THE ENGINEERING RECORD
PUBLISHED WEEKLY BY THE
McGraw Publishing Company
MAIN OFFICES:
114 LIBERTY STREET, NEW YORK.
BRANCH OFFICES:
PHILADELPHIA: Real Estate Trust Bldg.
CHICAGO: 1140 Monadnock Block.
CLEVELAND: Cuyahoga Building.
LONDON OFFICE: Hastings House, Norfolk St., Strand.

SUBSCRIPTION RATES:
United States, Canada, Cuba and Mexico....$3.00 a year.
Foreign subscription .... 6.00 a year.
25 shillings. 25 marks. 31 francs.
Foreign subscriptions may be sent to our London office.

NOTICE TO ADVERTISERS.

Changes in advertisements intended for a particular issue should reach the office of THE ENGINEERING RECORD by 10 A. M. Monday of the week of issue. New advertisements can be received up to noon of Wednesday of the week of issue.

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Entered at the New York Post-Office as Second Class mail matter.

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Of this issue of THE ENGINEERING RECORD 12,000 *copies are printed. Total circulation for* 1906 *to date* 130,000 *copies. The total circulation for* 1905 *was* 640,500 *copies, an average of* 12,317 *copies per week.*

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Government Aid for Research Work on Concrete.

All who have watched the development of our definite knowledge of a true scientific nature regarding the properties of concrete, with and without steel reinforcement, have been impressed by the trifling gain each year and the enormous duplication of effort in making tests in different parts of the country under conditions which render the results only roughly comparable. While concrete and reinforced concrete construction is progressing with astonishing rapidity and boldness, scientific knowledge of these materials barely creeps forward. The result is that a great many cities are witnessing the construction of concrete works which must be regarded with considerable distrust, not necessarily as being absolutely unsafe, but as typifying a sort of reckless gamble with fate over the true distribution of strains in a material of which we know little definitely. The result of this ignorance is of two-fold character and equally serious in either aspect. In the first place it is probably true that a great many people are endangered by working in unsafe buildings, which never should have been erected. Some of these structures are defective because of poor design, but the greater number are probably unsafe because the workmanship was poor. These conditions are not often due to a desire to swindle, but simply to ignorance and overconfidence in the value of imperfect knowledge. On the other hand, there are a few places where these dangers have been appreciated by the local authorities, who, to prevent their occurrence, have passed very strict regulations concerning such structures, no matter how well designed, actually preventing their use. This has not been done in a spirit of prejudice against the use of concrete and reinforced concrete, but as a safeguard against disaster until the technical data on which the design of such structures must rest are definitely obtained by methods open to no sound criticism.

At the present time there is a Joint Committee of numerous technical societies engaged in procuring such data. It is probably as thoroughly representative and competent as any committee for such a purpose that was ever appointed. Its members are giving their services without payment and are actually paying out considerable sums to attend the meetings of the main committee and its sub-committees. Some money has been raised for its purposes and it is probable that this amount can be raised annually for some time to come. The committee has now carried its work so far, however, that it recognizes the further development of the necessary tests at the rate the country's interests demand must depend on a liberal federal grant of funds. At least $100,000 should be given for the coming year's work and the same amount for the next year. Although The Engineering Record is opposed to government work for which private laboratories are equipped it is heartily in favor of this request. It was not made until an attempt had been made to carry on the work in private laboratories. Investigations have been made with all the precautions that expert advice considered desirable, yet the results are bitterly disappointing. The amount of work accomplished at different laboratories has been very small and the results are not comparable. It is a well-known fact that in tests of mortar and concrete the methods of manipulation of trifling details of the construction and testing of briquettes, blocks and beams have a great influence on the results. The American Society of Civil Engineers has had a committee working for some years to determine the best methods of testing cement and its report has not yet been made, which fact will indicate to those unfamiliar with the subject the importance of the details of testing.

The only way in which the information required for a thorough understanding of concrete and reinforced concrete construction can be obtained is by comprehensive experiments made at one place by the same staff of experimenters. That is the one important lesson the work of the Joint Committee has taught up to the present time. The government now has at St. Louis a well-equipped laboratory where some work of this nature has been carried on. The importance of this work has led the President, it is understood, to appoint recently a committee of advisory engineers to supervise this research. The opportunities at St. Louis are excellent for conducting the investigations which are so desirable, and it is to be hoped that Congress will furnish the means. It should be borne in mind that help is not asked for anything that private means and private services have been or might be able to secure, but only for conducting the experimental work that experience has demonstrated to be beyond the reach of any laboratory without government help. And no assistance is requested in the labor of studying and digesting the information furnished by the results of these tests. In other words, Congress is asked to furnish only such help as it already affords through various executive departments to other business interests of a national character, and this help is to be extended under the direction of an advisory board appointed by the President. If there ever was a legitimate case for asking federal assistance for a scientific or industrial object, this is certainly such an instance.

A word should be said concerning the national character of the data it is desired to collect. In the large cities of the country concrete is now being used for buildings, bridges, sidewalks, sewers and other purposes to an extent that nobody foresaw ten years ago. On the railways it is becoming invaluable. But its greatest service, in some respects, is on the farms of many parts of the country. In a few favored sections, where timber and stone are plentiful, the value of concrete in rural districts is not apparent, but it is only necessary to consider the dairy buildings, cisterns, fence posts, silos and other structures of this material which are coming into favor at an astonishing rate to appreciate what a boon concrete is to the agricultural and dairying interests. In mining operations, also, it is just beginning to gain a foothold and nobody can foresee all the help it will afford in overcoming some of the problems of that industry. In many of the multifold uses to which it is put, concrete can be employed without any very marked technical attainments on the part of the user, but in many new fields to which it is being applied accurate technical knowledge is essential, and this knowledge can only come from the researches which it is hoped Congress will authorize at St. Louis. It should be added that these researches not only relate to subjects involving the nature of stresses and strains in beams and slabs, but also the effect of changes in the character and amount of the different ingredients of which concrete is composed. It is understood that the tentative programme for the investigations is so laid out that when the work is done the information furnished by the tests will cover all experimental data of fundamental importance to the user of concrete in any part of the country. This information can be distributed by the various publications of different government bureaus, and can be used by the government officers and other employes without any regard to the study of the data which will be made by the joint committee of technical societies.

A further reason for giving federal assistance to this undertaking is that it is intended to have representatives of all government bureaus using concrete on the committee supervising the tests. In this way it will be certain that the special needs of every branch of government work will be represented, and no bureau or department will be duplicating the work of another, as is the case in too many lines of government investigation. The great quantities of concrete employed on the works under the direction of the War Department, the Reclamation Service and other branches of the executive administration in themselves warrant Congressional assistance in these investigations, apart from the importance of the work to public and private interests in all parts of the country. Congressional help will afford the desired data in accurate form in two years. Without such assistance the information will be many years delayed in its appearance, and the dangers and extravagance that characterize many features of concrete construction to-day will continue indefinitely.

The Sea-Level Plan for the Panama Canal.

A careful examination of the report and plans of the majority of the Board of Consulting Engineers to the Isthmian Canal Commission distinctly conveys the impression of a broad treatment of the Isthmian Canal question. It may be, as the President said, that the foreign members of the Board were more or less influenced by European practice, but even if that be admitted it is quite possible that their resulting engineering views regarding "convenient accommodation" of inter-ocean navigation at the Isthmus may be more nearly adequate to a proper treatment of this world question than if their experiences had been more contracted or limited to inter-lake or inter-lake and river problems. However that may be, the charge of narrow, foreign provincialism cannot be brought against any of the three American members of the Consulting Board who signed the majority report nor against the member of the Isthmian Canal Commission who favors a sea-level canal.

A sea-level canal, i. e., an open, unthrottled ship waterway across the Isthmus, certainly has the advantage of being unobstructed. That simple fact cannot be denied. It may be claimed that obstructions in the shape of locks, especially locks in series, are of such a nature as to be capable of being turned to partial advantage and by some ingenious, albeit complicated, processes, even to give an increased freedom to navigation and capacity to the canal. When, however, the situation is cleared of all obscurity of involved arguments it is probable that even the most enthusiastic advocate of a lock plan will admit that constricted sections of prism, through which no vessels can pass until the obstructions in the shape of gates are slowly removed, do not by themselves either increase freedom of navigation or the capacity of a canal. Nor, again, is it exactly clear to an engineering mind how, in the abstract, the lifting and dropping of ships through considerable heights by the agency of complicated lock machinery and the nicely adjusted operation of appliances subject to constant and imminent danger of derangement can, after all, make a canal more safe for the passage of ships than that canal would be without such locks. Inasmuch as the Board's report in favor of the sea-level canal is free from laborious arguments to show that locks and other constrictions and obstructions to navigation are not what they obviously seem to be, the general argument and treatment of the problem is clearer and more easily followed than in the minority report.

One of the most prominent and interesting features of the plan is the control of the Chagres River, which is accomplished by the construction at Gamboa of either a great earth dam with a masonry core reaching down to bedrock or a masonry dam with the same foundation as the core wall. This great lake, with its water surface at a maximum elevation of 175 ft. above mean tide, receives all the flood waters of the Chagres above the point where that river cuts the canal line. It acts as a most effective sedimentation reservoir, so that none of the sediment above Gamboa can find its way into the canal prism. Controlling sluice gates of the Stoney or other type would permit the waters of Gamboa Lake to enter the canal prism at a maximum rate of 15,000 cu. ft. per second after a flood. As that volume of water would produce a current in the canal, if it all flowed one way, of only about a mile and a quarter an hour its effect upon navigation is negligible.

All the tributary streams between Gamboa and the sea are either cared for by independent diversion channels or kept from entering the canal by suitable dams where the topography of their water-sheds permit such treatment, or by means of settling basins before their waters enter the canal. All the streams between the Culebra Divide and the Pacific Ocean are similarly treated. In this manner essentially all the sediment of the Chagres River and its tributaries and of other streams is prevented from entering the canal prism, thus greatly reducing the cost of canal maintenance by practically eliminating dredging.

The real problem of this plan is the excavation of the great cut through the continental divide known as the Culebra Cut, extending for a distance of about eight miles through the highest part of the Cordillera. The Board, and it is fair to assume its minority as well, regards this part of the work as a matter of transportation. It is obviously simple and easy enough to excavate the earth and rock, but the real problem is one of transporting the excavated material from the excavators to suitable dumps or receiving places. This excavation and transportation problem appears to have received careful and extended consideration by the Board. The details of the study are not given, but it is stated that the study has been made and that "it is as clearly demonstrable, as any estimate of rate of progress and time for the completion of any great engineering work can be, that after the full installation of plant not less than 100 steam shovels may be continually engaged . . . until the amount of work remaining to be done becomes too small to afford space for the operation of the whole plant." Further, "it can be demonstrated that as much as 20 million cubic yards of material classed as rock may be annually removed from the summit cut."

These estimates of rate of progress and of the consequent time required for the completion of the work are all based upon liberal allowances for the delays caused by the rainy season on the Isthmus, by the demoralizing effect of the climate and by the inefficiency of the available labor, and upon a much lower average rate of excavation per steam shovel than has been shown by actual experience on the Isthmus to be the reasonable average capacity of those shovels. In this manner the Board shows that the entire 110 million cubic yards of material in the great cut "can be removed within ten years." As this excavation is the controlling element in the time required to complete the sea-level canal it is certainly reasonable to accept the majority estimate of the time of twelve to thirteen years for the attainment of a sea-level canal across the Isthmus.

The standard bottom width of the sea-level prism is 150 ft., with the side slopes of 1 vertical on 1.5 horizontal in firm earth, but in hard rock its width is 200 ft. with practically vertical sides, the minimum depth of water being 40 ft. These dimensions are criticised by the minority of the Board as producing a "narrow" waterway. The criticism, coupled with the failure of the minority to state the well-known dangers of submerged channel banks found to such large extent in its plan, is scarcely ingenuous. The limits of the sea-level channel are absolutely defined by the banks at the waters' edge. In a large portion of the lakes of the minority's plan, the limits of the channel are submerged and hence not visible. The difficulties of submerged channels are by no means entirely avoided by buoys. The trouble which the submerged channels in St. Mary's River and in Lake St. Clair have given to pilots is well known, although these channels are navigated many times each season by captains who know them as well as the streets in front of their homes.

Just what additional width should be given to a submerged channel, over one not submerged, in order to secure equal safety to navigation, can scarcely be stated, but in order to attain that end the submerged channel should probably be not less than twice the width of the channel with visible banks. Ample experience in every maritime ship canal in the world has shown the entire safety for the navigation of sea-going ships in canals of much less width than that proposed by the majority of the Consulting Board. It is hypercritical to state that the ample dimensions proposed for the sea-level prism, greater than any heretofore suggested for such a purpose, are such as to produce a narrow or to any extent a dangerous waterway.

The criticisms made by the Isthmian Canal Commission on the estimates of time and cost set forth in the Board's report do not seem to be well based. It is to be remembered in this connection that the Commission practically served notice to the Consulting Board in the letter transmitting to the latter plans and papers for its action that a sea-level plan would find no favor in its councils. Under these circumstances, the Commission having practically recorded its pre-judgment against a sea-level plan, was bound to set up unfavorable criticism wherever possible. The additions made by the Commission to the Board's estimate of cost have little or no foundation, as both the unit prices and estimated quantities adopted by the Consulting Board are almost extravagantly full. It has already been shown in a previous issue that the excessive cost of maintenance charged against the sea-level plan is unwarranted, and as between the Commission's estimate and that of the Board regarding the matters of diversion channels and comparatively small diversion dams there is no doubt that the Board's estimate may be safely accepted.

The estimate of time made by the Board for the construction of the sea-level canal is certainly liberal. The work required in the sea-level construction is simply digging and transporting the excavated material, the complete program for which can be laid out and prearranged with a definition and degree of certainty which in no wise attaches to the various classes of masonry, machinery and other work requiring great numbers of skilled laborers characterizing the lock plan. The Board's estimate of time carries in it the most liberal allowances for all elements of delay, as has already been set forth, and when 25 per cent. was added to the time estimated upon such a liberal basis every possible contingency was even more than abundantly provided for. There is far more reasonable ground for expecting the sea-level plan to be completed within ten or twelve years than that the lock plan can be finished within eight to nine years. The statement therefore that fifteen to twenty years will be required for the construction of the sea-level plan is thoroughly misleading and not warranted by any fair or judicial consideration of the elements on which an estimate of time should be founded.

Philadelphia and Water Meters.

Every city seems to have some topic upon which it is particularly sensitive, so that any public mention of it, except casual reference implying no expression of opinion, at once fills the daily papers with columns of communications from "Pro Bono Publico" and all the others. In Philadelphia, this subject, which must only be mentioned after crossing one's fingers, is water meters. Just why the people of the city are so unanimously and vigorously opposed to this excellent device nobody seems to know, but the fact remains that any suggestion for its introduction is a declaration of war. Possibly Major Gillette, the new chief of the Bureau of Filtration, was not aware of this supersensitive feeling toward meters, or possibly he felt, like the other warrior who is now directing the police department of New York, that public opinion was none of his business, and his duty was to administer the affairs of his bureau without regard to any outside conditions. So he has advocated "metering every consumer's pipe, including city buildings and others that do not pay water rates, so that the record of the meters will check the record of the pumps." This has called out the criticism natural to expect in Philadelphia.

In the outburst of criticism that this suggestion has aroused, it is gratifying to observe that Mr. John C. Trautwine, Jr., formerly chief of the Bureau of Water, has come to the aid of Major Gillette. Probably nobody else knows so well the needs of the Bureau of Water, the advantages of a restriction of waste and the trend of thought of Philadelphians. In his letters to the daily papers he has brought forward arguments for restricting waste with a deftness and occasional touch of humor that must make converts for the cause he advocates. This method of handling the subject is so good and the object to be attained so important, that it is gratifying to observe and record Mr. Trautwine's rally to the defense of the meter. Few men who suffered the experience he did during the last year of his public service would care to take up unofficially the unpopular side of such a question. The situation in the city is one that demands great tact in its handling, and any roughshod attempts to thrust a universal meter system on the people will probably result in the overthrow of the administration. This fact ought to be kept in mind, not only because the present administration is apparently animated by an honest desire to furnish the city with good government, but also because there is no real necessity for a universal meter system in Philadelphia at the present time. This journal looks forward to such systems in most cities eventually, as soon as consumers learn by experience that the meter saves them money unless they are careless. There is a decided prejudice against the appliances at present, however, and the worst possible way to attempt to overcome it is to try to place a meter on every service.

This journal confidently believes that it has done more than all other publications to spread a knowledge of the ways to prevent the waste of water. For a number of years its editor made special annual investigations in Europe of the methods followed there to prevent waste and the results of these investigations did a great deal to prepare the way for the meter, an instrument then in its infancy. Since that time it has been a consistent advocate of the legitimate use of meters, but it has yet to find any sound reason for such a wholesale introduction of them in defiance of very strong public sentiment as is now proposed in Philadelphia. A water meter has two distinct purposes. The first is to serve as a measuring device by which the amount of water used by a careful consumer is determined, so that he need pay for only what he uses. The second purpose is to check waste by making the careless consumer pay for what he squanders as well as what he really uses. At the present time the waste of water in Philadelphia is far more important than any other consideration. This waste is probably taking place on less than twenty-five per cent. of the services, and does not amount to very much in a considerable number of those cases. In a report made by Mr. Trautwine in 1898 he advocated placing "about 45,000 meters, or enough to provide for all our manufacturing establishments and about one-fifth of our dwellings." That is as many as there is any real necessity for installing in the city now, but there is decided need for that quantity.

The city's filtration works have cost large sums to build and will cost considerable money to run and maintain. These charges added to the cost of the water as formerly supplied will make the actual expense to the city for delivering a filtered supply quite heavy. Every citizen should have all the water he needs in his home and in his place of business at its actual cost to the city, but he should not waste any unless he pays for it. The meter is the instrument which makes this system of payment possible. Four-fifths of the people of the city do not need to have their services metered except as a convenience to themselves. One-fifth of them are wasting enormous quantities of water and the places where they live must be inspected and metered until the waste is stopped, if the citizens do not wish to drink some unfiltered water or to spend millions of dollars for the immediate construction of new filters not yet planned. There is no alternative. Either four-fifths of the people must be heavily taxed for the carelessness of the wasteful one-fifth or the waste must be stopped by meters. Even if the latter course is adopted, which should be the case, there is no need for a universal metering of the service pipes, and the opposition to such a plan is not only in keeping with Philadelphia traditions but entirely justified by the present condition of the water works and the finances of the city.

Notes and Comments.

The Pension Outlay of the Pennsylvania R. R. Co., during the six years ending Dec. 31, 1906, amounted to $2,004,087.59, exclusive of the expenses of managing the department. During the period covered by these figures, 2,700 employees have been retired as pensioners under the rules of the company, and 890 of these men have since died. Of the total number, 688 were between the ages of 65 and 69, and 546 of them were retired on their own request with the approval of the employing officer.

The American Society of Civil Engineers, through its Board of Direction, has taken a step that both American and foreign professional societies have long debated, by admitting to its membership a woman qualified for one of the lower grades. This young woman is a graduate of the civil engineering school of one of the large universities and has lately been doing good work in the drafting department of a leading bridge company. She is qualified in every respect for admission to the society, under its rules, and the Board very wisely admitted her. There should be no objection to this on the part of the membership. There is considerable work of a technical nature done in all large offices that women can perform very efficiently. It is the general testimony of employers of large numbers of persons on work requiring careful attention to details, that women give better satisfaction than men, so long as the work is not beyond their knowledge. There is every reason to welcome their presence in office positions requiring technical knowledge, as soon as they have that knowledge, and if their education and work justify their admission to technical societies the latter ought to welcome them gracefully or make haste to change their constitutions so as to prevent the dreaded female invasion.

The Pollution of New York Bay is a subject that has received the careful attention of many engineers, particularly those connected with the New York Bay Pollution Commission. This body, appointed in 1903 by the Governor of New York, presented a report which was reviewed at considerable length in this journal on May 6 of last year. The main lesson the commission drew from its work was that more investigations were needed before any adequate solution of the problem involved in the discharge of sewage into the bay should be attempted. Further consideration of the subject has strengthened the commission in this opinion, and it accordingly is urging the passage of a bill authorizing the Governor to appoint a new commission, the private members of which will be suitably compensated, for the purpose of continuing the investigations, and, in association with representatives of the State of New Jersey, of formulating some plan for interstate sewerage control. By the time some scheme for such control has been worked out, it is expected that the necessary data for definite action can be acquired. This plan has much to commend it. The information concerning the conditions in the bay as well as the general subject of the discharge of sewage into such bodies of water are too indeterminate at present to warrant any very positive decisions concerning the pollution of the harbor. To collect the information that is needed will probably require about two or three years' work. This can be done most satisfactorily by means of a staff of paid assistants working under the general direction of competent specialists who are members of the proposed commission. These specialists need not put much of their time on the work of supervision, and their charges need not be very high in consequence. Other members of the same body could give more attention to devising some organization for an interstate metropolitan sewerage commission. The State of New Jersey already has two commissions, the State Sewerage Commission and the State Riparian Commission, which might be delegated by the Governor to assist in this work.

The Pennsylvania R. R. Terminal in New York is discussed as follows in the annual report of Pres. Cassatt, made public on Feb. 28: "The construction of the tunnel line into and through the city of New York has been steadily prosecuted during the year. All the real estate required for the terminal station has been purchased and also the greater portion of that needed for the terminal yard in Long Island City. On the section between Newark and the Hudson River, the drawbridge over the Hackensack River is under contract, and the work on the Bergen Hill tunnel, which is being driven from both ends, is to be further expedited through the central shaft from which headings are driven in both directions. In the North River tunnels, the shields are at work on both sides of the stream, and it is confidently expected that they will be connected and the iron lining in place before the end of the year. The excavation for the station site and the building of the retaining walls are steadily progressing; the power house from which the terminal station will be operated is under construction, and the tunnels under the city of New York are being driven westward from the main shaft at First Ave. and also in both directions from the intermediate shafts located on 32d and 33d Sts. between Fourth and Madison Aves. On the East River section, the shields on the Manhattan side are in place and working towards the river; and, while the shafts on the Long Island side are not yet completed, a considerable amount of work has been done between those shafts and the eastern portal of the tunnels in Long Island City. The power house in that city is in service and is supplying the electric lines of the Long Island Railroad. Nothing has occurred to seriously delay the progress of the work or to suggest any special difficulties in carrying out the general scheme of construction."

THE NOVEL METHODS OF EXCAVATING BUILDING SITES IN CHICAGO.

The opening of the subway freight tunnels of the Illinois Tunnel Co. in the downtown business districts of Chicago has provided a most economical method of disposing of the material from the excavations for the footings and the basements of new buildings in those districts. The methods of carrying on these excavations, and even the methods of erecting the structures for which such excavations are made have also been changed in a great measure in a number of cases since the service offered by the tunnels has been available. Something over 40 miles of tunnels have been completed in a district about 2 miles long by 1.5 miles wide, the center of this district lying practically at the center of the most congested business portion of the city, in the vicinity of the new government building. Most of these tunnels carry a single 24-in. gauge track and are about half oval in cross-section, being 7.5 ft. high and 6 ft. wide in the clear, with an arched roof and a flat floor. They are generally about 40 ft. below the street surface. Their construction is carried on in such a manner as to avoid any possibility of causing settlement of the buildings along the streets under which they pass.

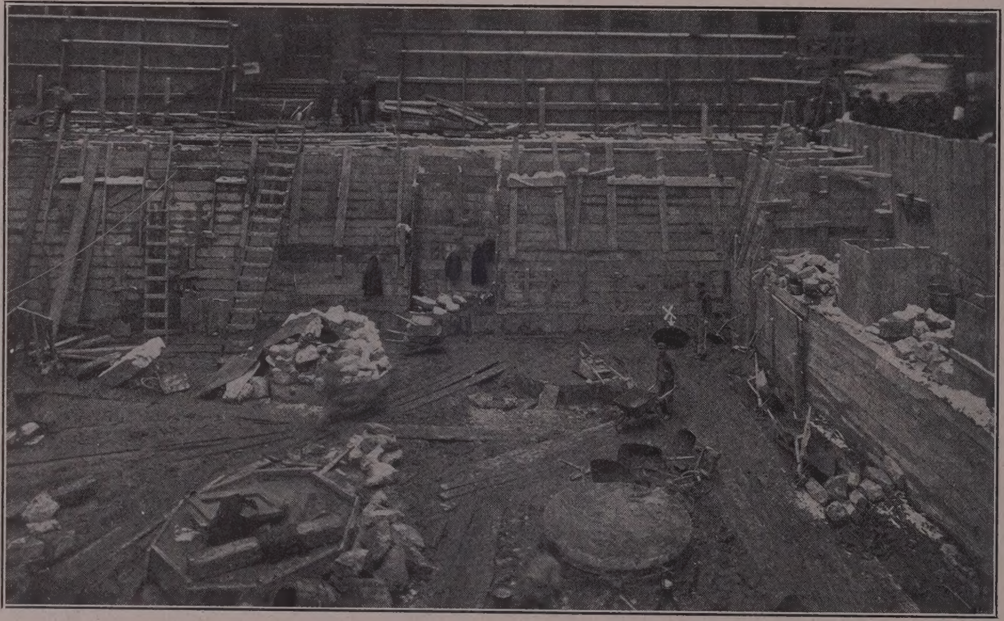
A tunnel is built under nearly every one of the streets in the district covered. The buildings to be served are connected with the tunnel in the adjoining street by various arrangements of switching branches, depending on the service required. Two general methods of handling the material from the excavations for new buildings have been followed in the work that has been done thus far. One of these is to first remove the structure on the site and then sink an inclined shaft from the basement of the old building to a by-pass connection with the tunnel. The excavated material is dumped down this shaft directly into cars on the track in the by-pass. The other method is to provide a similar connection with the tunnel and to make the greater part of the excavations for and build a large portion of the footings of the new building before the old one on the site is torn down. Both of these methods have been varied in details to suit local conditions. The greatest advantage from a construction standpoint in making use of the tunnels in removing the excavated material is that the building contractors can proceed with other work without being interrupted by the teams which are required in hauling away the material if the tunnels are not employed. Again, the usual obstruction to traffic in the streets adjoining buildings under construction is almost entirely removed until the erection of the superstructure of the new building has been started.

The character of the foundations in the business district of Chicago where the majority of the tall buildings has been erected have been discussed very fully in this journal at various times. The value of the tunnels in connection with building construction may be shown better, nevertheless, by a brief reference to the nature of the foundations on which this part of the city is largely built. Bed rock lies at a depth of 90 to 120 ft. below the original surface in the district under which the tunnels have been constructed. The original surface was a swamp. The present grade of the city is 10 to 14 ft. above this old swamp and 14.5 ft. above the normal level of Lake Michigan. The grade was raised with various kinds of filling material. From the bottom of this filling to within 16 ft. of bed rock quicksand, loam, several kinds of clay, an occasional pocket of gravel and boulders reaching 8 to 10 tons in weight, are encountered. The clay is largely of a blue variety, which carries considerable water and has about the same consistency as stiff putty. It has considerable carrying capacity when confined, many of the largest buildings in the city being built on float footings on it. Below all of these varying materials is a stratum of hardpan overlying the bed rock.

The more recently built tall buildings in the city have been erected on concrete footings carried down to bed rock. These footings are spaced as required under the side walls and under the principal columns of the building. They are made from 5 to 10 ft. in diameter and are belled out at the base to provide additional bearing on the bed rock. It is in the excavation of the open caissons in which these footings are built and the taking out of the material which has to be removed in making new basements that the tunnel has proved specially valuable.

A typical example of the general method of making the excavation after the existing building on the site of the new structure has been partially or entirely razed is the Majestic Theatre building. This building is 72x192 ft. in plan and 20 stories high. It is built on a number of the concrete footings carried down to rock in the usual manner. One of the tunnels is built 42 ft. below the center of the street on which the building fronts. A turnout connection is made from the bore of the tunnel, joining the latter at both ends. The outer line of the turnout is just inside the curb line of the street. An inclined chute, 4 ft. in diameter, was built from the floor of an areaway under the sidewalk and level with the basement floor, down to the turnout. This chute was lined with steel sections to prevent caving and leakage of water. The steel lining passed through the concrete arch roof of the tunnel and ended just inside the intrados of the arch.

The material excavated from the caissons was hoisted up in buckets and dumped into wheelbarrows. The wheelbarrows were run to the mouth of the chute and the material dumped into the latter from them, passing directly into a car on the track in the tunnel turnout below. The lining of the invert of the inclined chute to half way up the sides was made perfectly smooth to avoid intercepting any of the materials. The entire excavation for this building amounting to more than 18,000 cu. yd. was removed in this manner without teams and wagons after the tunnel connection had been made. The construction of retaining walls around the sides of the basement of the building and the placing of concrete in caissons already sunk were carried on without being interrupted by the necessity of wheeling the excavation from other parts of the basement or from other caissons to the tunnel chute.



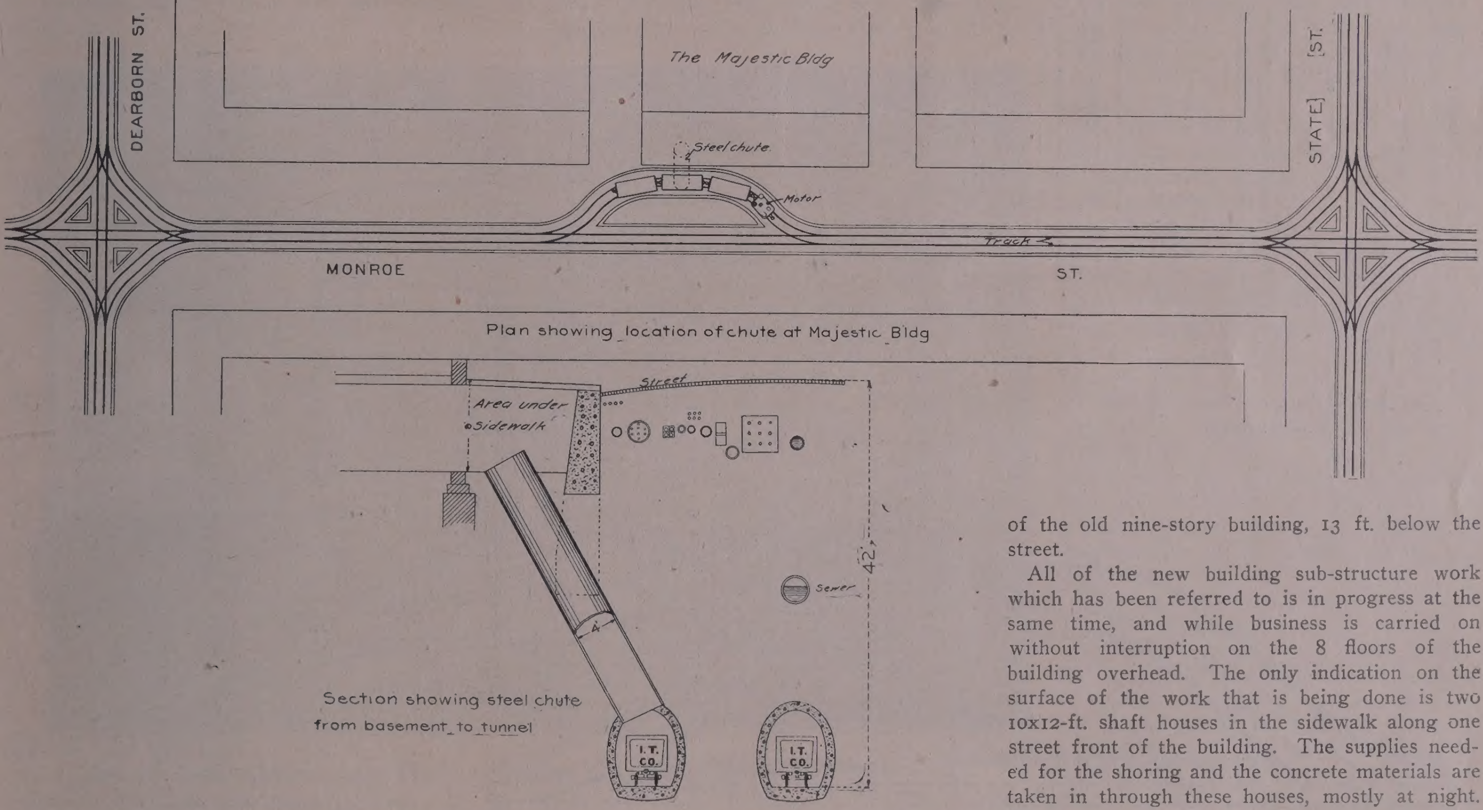
Majestic Building Foundations Showing Chute Leading to Tunnel.

The differences in the methods of prosecuting work under similar conditions on other buildings where the general method has been employed are simply in the details. As high as 2,100 cu. yd. have been removed through the tunnel from one basement in 24 consecutive hours by this arrangement. The best record by teams and wagons in removing material from excavations for basements and from caissons for buildings in Chicago, was 420 cu. yd. in 24 consecutive hours. This latter method required the contractors to stop all overhead work in order to secure these results. It also practically blockaded half of the street on which the work fronted. Both of these expensive and objectionable conditions are removed where the excavation is removed through the tunnel.

The general method of carrying on the excavations for new buildings under old structures on the site before the latter are removed is well illustrated in the work that is now being done on a new store building that is about to be erected for Marshall Field & Co. The retail establishment of this firm occupies an entire block, 342x385.5 ft. in plan, with the exception of a small 8-story building at one corner. The new building is on a corner of the block and will be 150 ft. square in plan. It will have 12 stories above the street grade and 3 below that grade. The remainder of the block is occupied by practically new buildings, with the same number of stories above and below grade, except a 9-story building on the corner adjoining the new building. When the building now under construction is completed the retail establishment will have an area of about 33 acres devoted to merchandising.

The site of the new building is at present occupied by an 8-story building in which a very important part of the retail store is located. The new building will be carried by 59 circular concrete footings, 6.25 to 10 ft. in diameter, carried down to bed rock. The bottom of the lower sub-basement of the building will be at approximately the level of the tunnel, 40 ft. below the street grade. The bottom of the basement of the existing building was only 9 ft. below the latter grade. In order to provide room for the two basements below that level and to make the excavations in the caissons in which the concrete footings will be built, more than 35,000 cu. yd. of material will have to be removed.

This material will be taken out entirely through the tunnels. Before the present building is vacated or torn down 29 of the excavations for the concrete footings will be sunk and those footings built. The present basement floor level will also be lowered 5 ft. at the same time. A connection has been made with the tunnel similar to the one at the Majestic Theatre building, and the materials from the excavation are being removed through it about the same as they were removed from that building. The concrete footings that are to be built before the old building is torn down are those which will carry interior main columns of the steel frame of the new structure. Most of these footings come directly under the columns which carry the floors of the building now on the site. Before the excavations for these can be started, the columns of the old building have to be shored and the loads on the columns carried by the shoring.



Arrangement of Tunnel Connection, Majestic Theatre Building.

The distance between the foot of the front sides of the two sets of cribbing carrying the ends of the four I-beams which directly support each of the columns of the old building temporarily, varies considerably. This distance necessarily must be sufficient to permit the excavation for the new footings to be made and for the concrete of the latter to be placed without disturbing the shoring. As soon as the old masonry footing of each column has been taken out, the excavation for the new footing which is to occupy the same site is commenced. When a depth of 3 ft. has been reached in the excavation a circular sheeting made of 2x6-in. tongue and grooved plank, banded with two ¾x3-in. iron strips, is placed around its sides. The material is then removed to a depth of 5 to 6 ft. below the bottom of this sheeting and sheeted again in the same manner. The remainder of the excavation is carried on in about the same way, unless quicksand is encountered.

The loads from five of the columns of the old building were transferred to the underpinning about the same time. The excavations for the five new footings on these sites were begun and were carried down practically at the same time. When these excavations were about half way down to rock, five more columns were underpinned and five more excavations commenced. The plan was thus to keep about this number of excavations under way in order to permit the maximum amount of construction to be carried on at the same time without the work on adjacent caissons conflicting.

The material taken out of the first few feet of each excavation is usually hoisted to the surface by a hand windlass in a bucket with about the same capacity as a wheelbarrow. After the excavation has reached a depth where the speed in handling these buckets is a factor in the progress, an electrically driven hoist, designed by the contractors and built by the Monagan Engineering Works, is used. This hoist has a regular drum controlled by a friction clutch on a gearing attached to the motor shaft. A spool is also operated by the motor through this gearing. The buckets in two excavations can be handled by each machine. The electric hoist is practically the only economical method that can be used while the building overhead is occupied, and has an additional advantage in that it requires very little room in the crowded space where so many operations are being carried on at the same time.

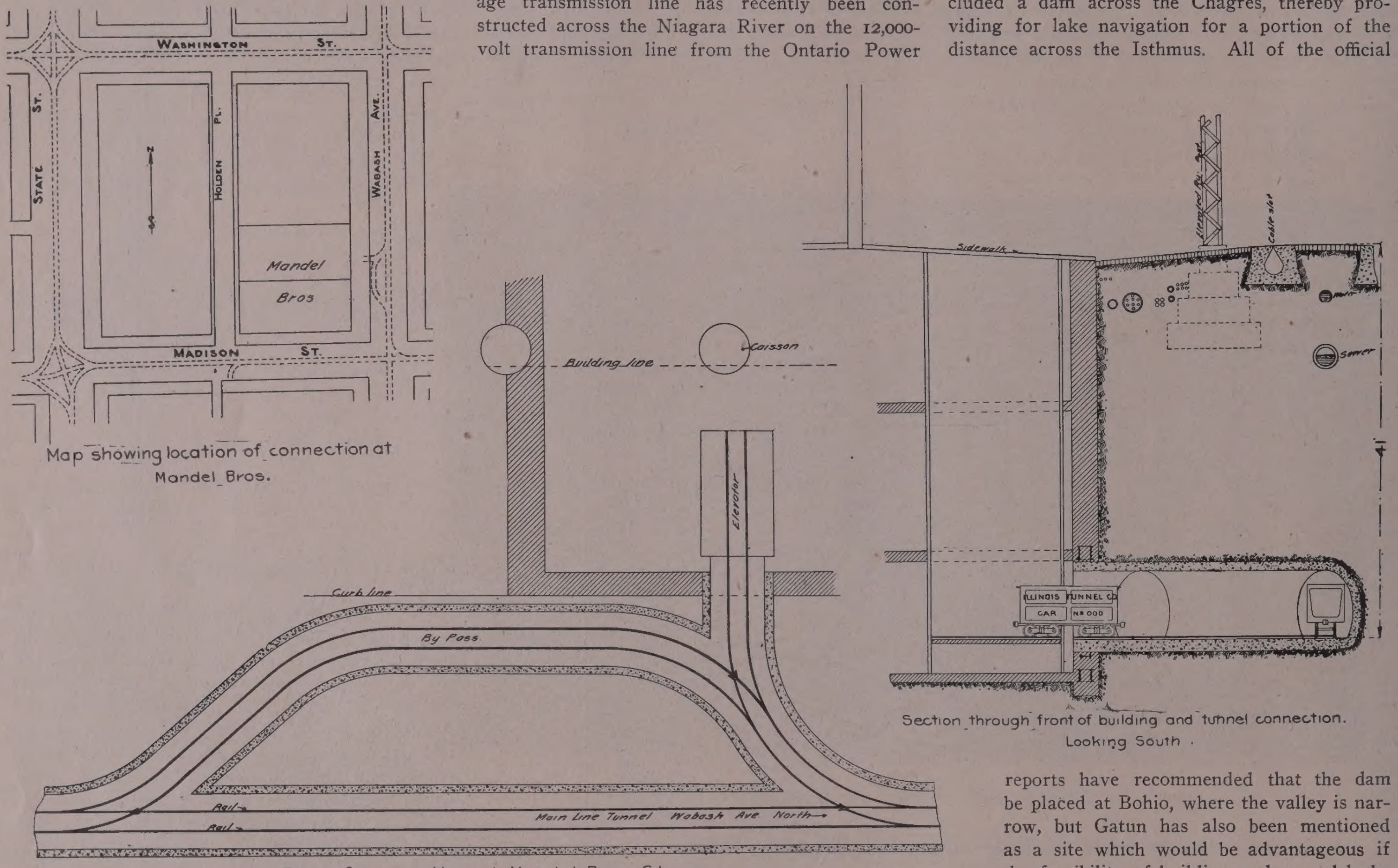
When the buckets reach the surface at the mouth of the caisson they are dumped on shoveling boards and the materials handled between the latter and wheelbarrows by hand. The wheelbarrows are run on plankways laid from the shoveling boards to the mouth of the chute leading down to the tunnel. The plankways can be placed so as to suit the conditions of the other work in progress. The wheelbarrows on them are more feasible for handling the material under the circumstances than any arrangement of tracks and cars that could be obtained. In order not to require unnecessary service of the tunnel company enough extra wheelbarrows are provided to keep the excavation in progress if intervals occur between the placing of trains in the tunnel by-pass to which the dumping chute delivers.

The 9-story building adjoining the 8-story one on the site of the new structure, although built in 1892, is on float footings. Five of these float footings along the abutting lines of the basement under the two buildings are being removed and will be replaced with concrete footings carried down to rock. The columns carried by the footings to be removed rest on the usual steel shoes. The shoes rest directly on pieces of railroad rails imbedded in concrete. Transverse to and under these pieces of rails are six to fifteen 14-in. I-beams, 14 ft. long, which rest on a second layer of 14-in. I-beams, 18 ft. long, placed transversely to them, and the second layer of beams is carried by a third layer 22 ft. long. The I-beams are all also imbedded in concrete. These footings have to be entirely taken out and replaced by circular concrete footings carried from bed rock up to the grade of the basement floor of the old nine-story building, 13 ft. below the street.

All of the new building sub-structure work which has been referred to is in progress at the same time, and while business is carried on without interruption on the 8 floors of the building overhead. The only indication on the surface of the work that is being done is two 10x12-ft. shaft houses in the sidewalk along one street front of the building. The supplies needed for the shoring and the concrete materials are taken in through these houses, mostly at night. The service available in the tunnel, of course, alone made possible this method of prosecuting the work.

The contractors for the construction of the footings of the new building and the removal of the present structure, Wells Bros. Co. of Chicago, started work on the excavations for the new building, Feb. 6. It is expected that 29 caissons which are to carry the interior columns of the new building will be completed and the excavation for the basements of the latter carried down as far as feasible by April 15. The old building will then be vacated immediately and will be wrecked by May 10, after which the footings are to be completed and the new building erected by Oct. 1, next. Although the rate of progress required to achieve such results is rapid, the contractor for the substructure work has done most of the work of the same nature in Chicago that has been carried on with the assistance of the tunnel service and is confident the time limit need not be exceeded.

The excavation for the basements and footings of an addition to Mandel Bros.' store, another large retail establishment, amounting to 42,000 cu. yd., was removed through the tunnel in a somewhat different manner. This addition is 82x155 ft. in plan and has three floors below and 12 floors above the street grade. The site was occupied by 3 and 4-story brick buildings in which business was continued until the footings and the excavation for the new building had been completed. A by-pass connection was made with the tunnel under the adjoining street. Toward one end of this by-pass a connection, at right angles to the tunnel under the street, was extended beneath the street front end of the site. The floor of the third sub-basement of the new building is 45 ft. below the street grade. A strip of excavation about 25 ft. wide across the front of the building was carried down to the floor level of the lowest basement by dumping the materials taken out through a chute which discharged into the tunnel cars placed in a manner similar to the arrangement described in connection with the other two buildings. After this strip was removed to grade the tunnel track was extended into the building. The excavated materials were then dumped directly into the cars. Twenty-nine of the footings under this building were built in 28 days, each requiring on the average 200 cu. yd. of excavation and the same amount of concrete. Mr. W. F. Lampman was superintendent for the contractor on this building and also has charge of the work on the Marshall Field building.



Map showing location of connection at Mandel Bros.

Section through front of building and tunnel connection. Looking South.

Plan of connection at Mandel Bros. Store.

Arrangement of Tunnel Connection, Mandel Bros. Store.

The material from the excavations is handled through the tunnels to an incline along the shore of Lake Michigan. The incline extends to the surface and across the tracks of the Illinois Central R. R., which parallels the lake, to an area that is being reclaimed to form a park along the business portion of the city. The general scheme of this park project and a concrete retaining wall, 6,100 ft. long, which the Illinois Central R. R. has built in connection with it, were described in The Engineering Record for Jan. 27, 1906. The tunnel company agreed to furnish free 1,000,000 cu. yd. of the filling material necessary in making the new park if the privilege of extending the incline track from the tunnels across a portion of the park already completed be extended to it for 1½ years. Approximately 600,000 cu. yd. of material, mostly from excavations, have already been hauled out and dumped on the new park site.

The tunnel system of the Illinois Tunnel Co. was built by the Illinois Telephone Construction Co., Mr. George W. Jackson, general manager and chief engineer. The operation of the tunnels is also under the supervision of Mr. Jackson as general manager and chief engineer of the Illinois Tunnel Co.

A Transmission Line River Crossing.

A long-span river crossing for a high-voltage transmission line has recently been constructed across the Niagara River on the 12,000-volt transmission line from the Ontario Power Company's station on the Canadian side to Syracuse, N. Y., a distance of 157 miles. There are three three-phase circuits, each with three aluminum conductors of 19 No. 5 wires. At the river crossing they are carried on towers near the water's edge, 600 ft. apart. These are A-shaped structures of heavy steel construction, 55 ft. high, set on concrete piers. Where the cables pass over the edges of cliffs on either side of the Niagara gorge they are supported by steel cantilever arms projecting out from the sides of the bank.

The Maximilian Bridge at Munich, having two three-hinged masonry arches of 145 ft. span and 16-ft. rise, settled so much when the centers were struck that the surfaces of the hinges slipped past each other, preventing their operation as intended. The comments on the accident in foreign technical papers indicate that the thrust on the hinges and their unusual design proved inadequate to distribute the strains as intended.

The Gatun Dam of the Panama Lock Canal Project.

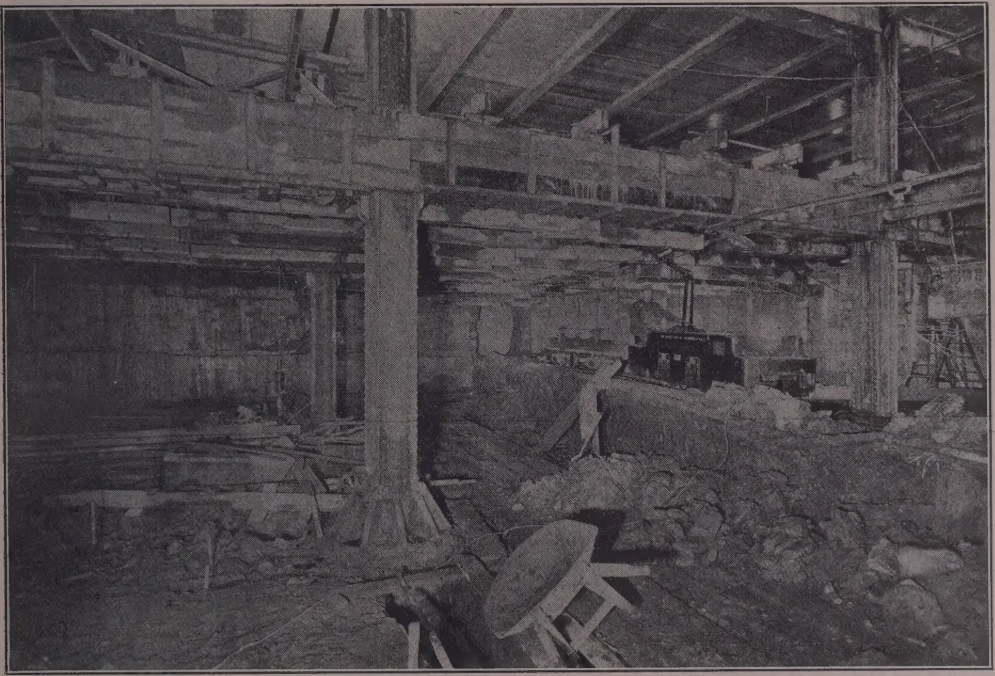
Extracts from the Minority Report of the Board of Consulting Engineers for the Panama Canal.

The controlling feature of the project with summit level at El. 85 is the earth dam across the Chagres at Gatun. The object of this dam is to form a great reservoir, or inland lake, in which the floods of the Chagres will be received and from which the surplus water will be discharged through sluices and the height of water in the reservoir regulated. Lake Gatun will be about 110 sq. miles in area and will form the summit level of the canal. The lake will also serve to impound water for lockage and other purposes during the dry season and to give free, open navigation in a broad waterway all the way from Gatun to Obispo. Every lock plan heretofore recommended for a Panama Canal has included a dam across the Chagres, thereby providing for lake navigation for a portion of the distance across the Isthmus. All of the official reports have recommended that the dam be placed at Bohio, where the valley is narrow, but Gatun has also been mentioned as a site which would be advantageous if the feasibility of building a dam and locks at this place at a reasonable cost were established.

Since the United States has taken charge at the Isthmus the Isthmian Canal Commission has had many borings made at and near these two sides. Those at Bohio, which are especially complete, show a greater proportion of water-bearing porous material than had previously been found. The maximum depth to the rock on the most feasible line for a dam at this place is 165 ft. below sea level. The borings made prior to September, 1905, at and near Gatun showed nearly everywhere an admixture of sand with clay and impervious material, with a maximum depth to rock of 204 ft. below sea level. Many of the borings, even those at considerable depths, encountered shells, wood and vegetable matter, all tending to show that the material had been deposited in currents too sluggish to transport gravel and other coarse material.

The borings were "water jet" or "wash drill" borings, made by first driving, when necessary, an iron pipe having an inside diameter of 2 or 2½ in. and then inserting a smaller pipe through which a jet of water was forced, washing the material in the larger pipe through the annular space between the two pipes to the surface of the ground. It was characteristic of these borings, and also significant, that in many cases it was not necessary to drive any casing; or, if one was driven, it was not necessary to drive it to the full depth, as the material contained enough clay to sustain the sides of the hole without the casing. Of 27 borings made before September with reference to the location of a dam at or near Gatun, no casing was used in 13 holes; in 3 other holes the length of casing did not exceed 20 ft., while in the remainder the length of casing ranged from 28 to 101 ft., but in no instance was the casing driven much more than halfway down to the bottom of the hole.

The depth to rock was shown to be so great, both at Bohio and at Gatun, that it would be costly and difficult in either case, if not impracticable, to excavate to the rock or to provide any efficient cut-off or stop-water extending from the surface of the ground to the rock; and if a dam were to be built without such cut-off the borings showed clearly that there would be less seepage beneath a dam built at Gatun than at Bohio.



Tunnel Connection and Electric Locomotive in Basement of Mandel Bros. Store.

In addition to the borings the commission had caused topographic surveys to be made at the site of the dam, which showed what was apparently an excellent site for locks on the high ground back of Gatun, and a suitable site for a diversion channel for conveying the water of the Chagres during the construction of the earth dam and for regulating works to control the discharge of surplus water from the lake to be formed by the dam.

Few borings had been made at the exact site selected for the dam, and none had been made at the sites selected on the high lands for the locks and the regulating works. The commission was therefore requested by the Board to have some additional borings made, both on the high lands and in the valleys, and also some additional topographic surveys. There are two deep depressions or gorges in the rock (see Eng. Record, Feb. 24, p. 215), which have been filled with alluvial material. The deepest boring penetrated this material 258 ft. before striking rock. The lower 50 to 60 ft. of the material in the deepest gorge was found to be for the most part porous sand and gravel, which was undoubtedly deposited at a time when the currents through the gorge were swifter than existed when the upper 200 ft. of the alluvial material was deposited. In the upper 200 ft. some of the latter borings show fine sand, while other borings near by show clay at the same depths, indicating, as do previous borings, that the upper 200 ft. is practically impervious material. There was an outflow from several of the borings which penetrated the gravelly material in the bottom of the deep gorge, although the tops of the casings were above the surface of the river. This showed conclusively that there was no near connection with the bed of the river; in other words, that the material covering the sand and gravel was impervious for a long distance.

A sample of the material washed from the ground during the boring operations, which had been collected in a pail without allowing any of the fine material to escape, was shown to the Board during its visit to the Isthmus. This sample showed material of sizes varying from sand to the very fine particles of clay which settled last and formed an impervious film over the surface of the coarser material deposited in the bottom of the pail. The samples of sand which had been obtained up to the time of the visit of the Board were fine, much more so than samples from borings at the Bohio site.

We believe as a result of the borings which have been made that if a large earth dam were to be built at Gatun, there would be no appreciable seepage under the dam, owing to the practically impervious nature of the material on which it would rest and to the fact that the more pervious material found at the bottom of one of the gorges in the lower 50 ft. is covered by a blanket of practically impervious material 200 ft. thick.

The borings on the high ground, at the site of the locks, the regulating works, and elsewhere, showed generally soft clay to a depth of 20 to 30 ft. below the surface, where indurated clay—a soft but compact rock—was found.

In making the design of an earth dam at Gatun it was thought best to provide a dam which could not be destroyed by any of the forces of nature, and which could only be destroyed by making excavations which would require a large force working for a long time. The cross-section of the dam has been given the unprecedentedly large dimensions shown on page 217 of The Engineering Record of Feb. 24. Its top is 50 ft. above the water level in the lake and 100 ft. wide; at the water level the distance through the dam is 374 ft., and at sea level the corresponding distance is 2,625 ft., or one-half mile.

It is intended that the downstream toe of the dam for about 200 ft. shall be composed of rock obtained from excavation in the canal prism, so that if there should be any seepage of water through the dam there will be material at the toe which cannot be washed away. The lower part of the dam, up to El. 50, or even to El. 80, is to be made from material dredged from the canal between the Gatun locks and Limon Bay, pumped by a suction dredge into the dam, the process being similar to the sluicing process employed in the construction of some important dams in the western part of the United States. By this process it is feasible when using a material like the alluvial material at Gatun, which contains both coarse and fine material, to separate the two and to deposit the coarser material toward the downstream slopes, forcing the finer material to the extent desired into the upstream portion of the dam. An embankment built in this way will be water-tight.

For the upstream slope rock obtained from canal excavation will be dumped as riprap, care being taken to provide an ample thickness at and near the level where the dam will be exposed to wave action.

The portion of the dam above El. 80 will be built of impervious material to a few feet above the water level, and at higher levels may be made of either earth or rock, as most convenient. It is expected that for the upper part of the dam spoil from the Culebra cut will be used.

While earth dams are in common use, and in many cases support greater heads of water than would exist at the proposed Gatun dam, it will be argued by many that in a great work like the Panama Canal nothing should be trusted but the most massive masonry dam on a solid rock foundation. At Gatun the rock lies at so great a depth that a masonry dam thus founded is impracticable, and without such foundation a masonry dam would be most unsuitable. It seems desirable, therefore, to enter to some extent into the discussion of the stability of the proposed earth dam.

Stability of an Earth Dam.—It is obvious that if a dam of this kind is to fail some part of its length must be pushed away bodily, or the earth of which it is composed must be carried away by currents of water. There are no other natural forces which can materially affect the stability of the dam. The horizontal pressure of the water in the lake per linear foot of dam is less than one sixty-third of the weight of the dam per linear foot, a pressure so small that it is obvious that it cannot move the whole mass, and there is left, therefore, as the only way in which a dam of this kind may fail, the carrying away of its parts by a current of water. The currents of water requiring consideration are those resulting from the action of the waves, from the rainfall, or from seepage through the dam.

The feasibility of protecting the face of the dam from the action of waves will hardly be questioned. The effect of the rainfall can easily be provided for, particularly on the main downstream slope, which falls but one foot in twenty-five.

It is impossible for water to flow over the top of a dam that is raised 50 ft. above the water level, and if the dam and the underlying material were strictly impervious there would be no water from the lake passing through it. On the other hand, if the material in or under the dam is somewhat pervious, there will be some water passing through which will appear at the surface, either immediately below the dam or toward the lower portion of the down-stream slope. The amount of water which will pass through somewhat pervious material in or under a dam depends upon the relation between the total head and the distance through the dam, and not, as is sometimes assumed, upon the total head against the dam.

If two dams are built under similar conditions, except that one has a thickness five times as great as the other, then there will be at the dam having the greater thickness only one-fifth as much seepage as at the other; that is to say, other things being equal, the seepage through a dam will be substantially in proportion to the depth of water against the dam, divided by the distance through the dam, giving what may be called the hydraulic gradient or slope of the line of saturation, which in this case does not exceed four per cent.

There have been many experiments on the vertical and horizontal filtration of water through various kinds of materials and with various hydraulic gradients. Some of these were made at the Lawrence Experiment Station of the Massachusetts Board of Health and others were made at the Wachusett reservoir of the Metropolitan Water Works, in Massachusetts, in connection with the construction of a dam similar to that proposed at Gatun. These experiments were made with materials of uniform character, through which more water would filter than through materials containing fine and coarse particles of the same average degree of coarseness, such as those found at the site of the Gatun dam, and they furnished results which confirm the statement already made that there would be no appreciable seepage under this dam.

If, however, a condition which does not exist be assumed, and all of the alluvial material beneath the embankment of the dam were considered to be a clean and reasonably uniform sand of medium size, the total amount of filtration would then be for the whole length of the dam only about 10 cu. ft. per second. Even this amount, which is much larger than would actually exist, is insignificant, and is less than one-half of one per cent. of the water supply available in the driest season.

Few engineers who have been connected with the filtration of city water supplies would hesitate to provide works which would permit the amount of water above stated to rise to the surface without carrying with it any of the earth, because they have a much more difficult problem in connection with the downward filtration of water, where the works must be so built that the sand will not be carried down with the water. The method followed in water filtration is to place coarse stones at the bottom of the filter and to cover these stones with finer and finer stones, and then with coarse sand, in order to retain the finer sand used for filtration. It is a simple operation to build the reverse of such a filter, which will permit the water to rise from the ground without carrying the earth with it.

It is not expected that there will be enough seepage through the Gatun dam to require any special treatment, but if there should be it could readily be taken care of by the method indicated, which has already been used with success in connection with a dam built of sand on a sand and mud foundation at Jeypore, India.

Upward filtration occurs frequently in nature, where water comes from springs near the base of hills, often in sandy or gravelly material, without carrying with it any appreciable quantity of earth.

Many small earth dams and levees have failed, owing to a passage being made through them by some burrowing animal, or by the water following some pipe or other structure built through the dam, but in the present case it is not proposed to lay any pipe or other structure through the dam, and a burrowing animal could not burrow through where the shortest distance at the water line is 374 ft.

It seems to be impossible that any of the particles of earth buried in the body of the dam could be moved by a slow seepage of water, except such particles as were soluble, which might, in the course of ages, be dissolved and carried off by the seepage water.

Some of the views held in respect to the movement of material in the body of earth dams are based upon observations of very small dams, and often of those negligently constructed or of a very narrow section, and have no place in connection with a properly constructed large earth dam.

A dam such as the one proposed is very heavy, the weight upon its foundation being about one ton per square foot for each 20 ft. in height of embankment. Under the highest part of the embankment the pressure would be 6½ tons per sq. ft. It is obviously impossible that with such a pressure upon the material any particles could be moved by the extremely gradual seepage of water through the interstices due to a difference of water level of less than 4 ft. in 100.

Such a dam as is here proposed, if not absolutely earthquake proof, is probably more nearly so than any other type of dam.

A comparison between the section of the Gatun dam and that of a few existing earth dams is shown in the illustration on page 217 of The Engineering Record of Feb. 24. The San Leandro dam of the Contra Costa Water Co., 120 ft. high, which supplies water to Oakland, Cal., is the highest earth dam in the world, and it was constructed in part by sluicing. The Pilarcitos dam, 95 ft. high, built in 1866 by the Spring Valley Water Co., which supplies water to San Francisco, is also one of the larger dams, although there are several others of about the same size, which have been successful. The Jeypore dam is introduced on the diagram because it was built of sand on a foundation of sand, mud and soil, and at a place where the material is very pervious, so that considerable water filters under and through the dam. It has, however, proved to be stable under these conditions.

The United States Reclamation Service has recently planned an earth dam to sustain a head of 100 ft. with a width at the water line less than one-fourth that proposed for the Gatun dam and with a proportionately narrow base. (This probably refers to the Belle Fourche dam described in The Engineering Record of March 3.)

It will be noted that these dams have a small section in proportion to the depth of water behind them when compared with the Gatun dam.

The nearest precedent in general design for the Gatun dam is the north dike of the Wachusett reservoir of the Metropolitan Water Works, of Massachusetts, which is two miles long and at the deepest place will have 65 ft. of water against it. The highest portion of this dike was built on exactly the plan proposed for the Gatun dam, namely, the fine material of which the dike is composed was deposited on the fine underlying material without the use of either masonry or sheet piling to prevent the filtration of water. Under portions of this dike the depth to the rock is as great as at the Gatun dam.

Plan of the Dam.—Its total length from the locks to the westerly end is 7,700 ft. About midway in the length of the dam there is rising ground in which it is proposed to excavate, as already indicated, a diversion channel through which the Chagres will flow during the construction of the earth dam.

The regulating works will be built mainly of concrete and will be located in part in the diversion channel and on each side of it. On each side of the rising ground referred to, and extending from it westerly to the high ground and easterly to the locks back of Gatun, there will be great earth embankments of the cross-section already described, which will together contain 21,200,000 cu. yd. of material. The westerly embankment will cross a French diversion channel. The easterly embankment will cross the French canal and the Chagres.

It will be feasible to begin at once the construction of one of the earth embankments, permitting the water to flow through the channel or channels at the site of the other embankment. It will also be feasible to begin at once the construction of the diversion channel, utilizing the material excavated in the embankments of the dam.

In the construction of the dam it is proposed to remove all trees, stumps and roots from its site and to excavate the surface material to such an extent that the impervious material of the embankment will come in direct contact with the impervious clayey material which is found nearly everywhere in this region; also to do any other work required to cut off the flow through any pervious material which further investigations may disclose. For such work an allowance of $400,000 for all dams has been made in the estimate of cost.

The diversion channel is to have a minimum width of 150 ft. and is to be excavated to sea level, or somewhat below it; although the lower part of the channel will be through indurated clay, it is proposed to place in it concrete where required for the protection of the channel or for the regulating works up to sea level, and to build in the channel to an elevation about 4 ft. above sea level the foundations of certain piers and walls, which will remain for a time at this elevation, so that they will form only a slight obstruction to the discharge of flood waters.

After the earthwork of the dam reaches a sufficient height to be beyond all danger of overflow, the piers and walls, which will be above water at low stages of the river, and which will have in them grooves for stop planks, will be built to higher elevations to furnish a ready means of turning the river through half of the diversion channel while the other half is pumped dry to permit the placing of the concrete of the regulating works, and by turning the river alternately from one side to the other the regulating works may be built without special difficulty.

Regulating Works.—The general design of the regulating works is shown on page 216 of The Engineering Record of Feb. 24. The central 150 ft. of their length, which will be built up from the bottom of the diversion channel, is to be a solid mass of concrete, having its crest at El. 69. The crest is to be made wide with the down-stream slope two horizontal to one vertical, making an unusually strong section.

On the top of the crest, piers 8 ft. in thickness, grooved for Stoney sluice gates, are to be built 38 ft. from center to center, having clear openings of 30 ft. These gates, as proposed, are almost exact counterparts of the gates provided for controlling the flow from the lower end of the Chicago Drainage Canal, but the sills are to be placed 16 ft. below the normal water level, instead of 15 ft., as at the Chicago Drainage Canal.

For the whole length of the regulating works the design is the same as the central portion, except that the concrete rests upon the surface of the rock or upon excavations made in the rock. The water passing through the central sluices will flow directly out through the diversion channel to the Chagres; that passing through the sluices nearer the ends of the regulating works will be caught by intercepting channels sloping toward the central portion, and will follow the course indicated by the arrows on the plan, flowing toward the central portion and thence out through the diversion channel.

The regulating works are capable of discharging 140,000 cu. ft. per second when the water in the lake is not more than one foot above the normal level.

It is thought that in connection with a great lake, such as here proposed, regulating works which can discharge a great quantity of water when the lake is at its normal level are preferable to an uncontrolled overflow spillway which will not begin to discharge water in any considerable quantity until a flood has raised the lake above its normal level.

With the uncontrolled spillway 2,000 ft. long, recommended by the Isthmian Canal Commission of 1899-1901, in connection with the Bohio dam, it was estimated that the water in the lake might be raised 5 ft. above its normal level by a maximum flood. With the regulating works proposed in connection with the Gatun dam it is estimated that the surface of the lake will never be raised by a maximum flood more than 2 ft. above the normal level, and with ordinary floods it would be feasible by beginning the discharge before the flood waters reached the lake to keep the surface from rising to any appreciable extent.

Such sluices as are here proposed would be very objectionable on a river or even at the outlet of a small lake, but in a great lake like that to be formed by the Gatun dam the currents toward the outlet will, under ordinary conditions, be inappreciable, so that the course of any floating substances will be determined by the wind instead of by the current, and they will be stranded on the shores; moreover, if, during floods, trees and other drift should be washed into the lake from the tributary rivers, they would not have time, on account of the great size of the lake, to reach the Gatun dam before the flood subsides.

Reduction in Cost.—The great quantity of material to be placed in the Gatun dam may cause it to be inferred that a structure at this place adds to the cost of the canal; but it should be borne in mind that the adoption of this site eliminates large expenditures for the canal and diversion channels between Gatun and Bohio. A comparison shows that there is a saving of $11,894,621 in the estimated cost of works by the change in the location of the dam, made up as follows:

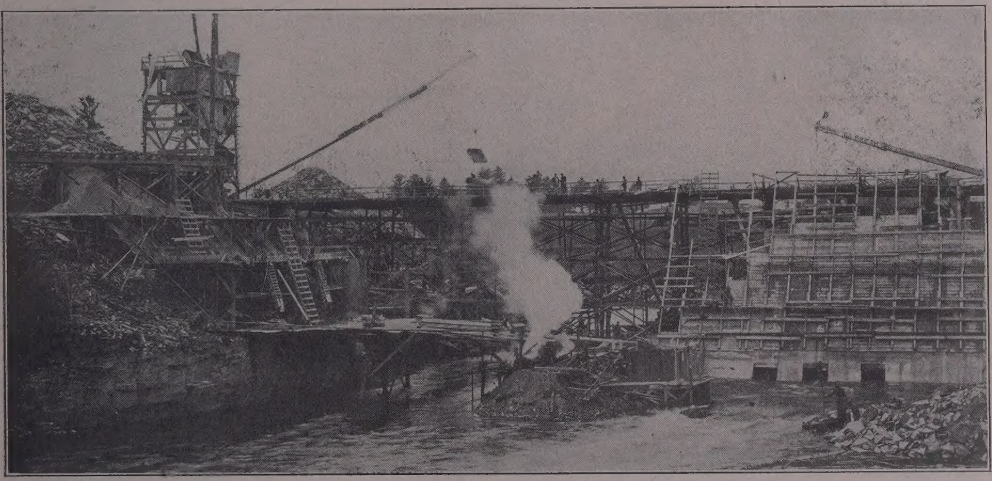
WORKS OMITTED.		
Bohio dam		$6,369,640
Gigante spillway		1,209,419
Canal between Gatun and Bohio		7,643,067
Pena Blanca outlet		2,448,076
Chagres diversion		1,929,982
Gatun diversion		100,000
20 per cent. for contingencies, etc.		3,940,037
Total for works omitted		$23,640,221
ADDITIONAL WORKS REQUIRED.		
Gatun dam	$7,788,000	
Panama Railroad diversion from Mindi to Bohio	2,000,000	
20 per cent. for contingencies, etc.	1,957,600	
Total for additional works required		$11,745,600
Amount saved by change in location of dam		$11,894,621

The estimates of the cost of the works omitted were made by the Isthmian Canal Commission of 1899-1901.

In the above table it will be noted that the locks have been omitted. The lock site at Bohio adopted by the Comité Technique of the New Panama Canal Company and by the Isthmian Canal Commission of 1899-1901 furnished a rock foundation for only two locks of the sizes then proposed. The requirement of the law under which the canal is being constructed makes it necessary to provide longer locks than can be accommodated with a rock foundation at the Bohio site. Moreover, it was thought desirable to make the lift to the 85-ft. summit level with three locks rather than with two, and the Gatun site affords an opportunity for doing this. The three large locks will cost more than the two smaller locks proposed at Bohio.

The adoption of Gatun as a site for a dam not only provides for reduced cost and a better lock site, but, as compared with Bohio, it offers several important advantages. The first of these is a large addition to the drainage area tributary to the summit level and to the amount of water available for canal uses, which is of special value during the dry season; the second is the great increase in the reservoir area, Lake Gatun having almost three times the area of the lake formed by a dam at Bohio; this permits storing water for the dry season and the reception of floods with a maximum variation of lake level of only about one-half of that taken by the first Isthmian Canal Commission for Lake Bohio. A third advantage is the extension of lake navigation 9½ miles toward the Atlantic from Bohio; a fourth is that the Chagres and all its important tributaries will be received into the lake at points so distant from the canal route that no deposit of suspended material will occur along it, and a fifth is that the water discharged from the lake will enter the Chagres at the point where it finally diverges from the canal so that no diversion channels or heavy protecting embankments will be required along the canal line.

A Novel Elevator with a rise of 495 ft. has been erected to the summit of the Burgenstock near Lake Lucerne, for sight-seeing purposes. The entrance to the car and space for its operating mechanism are tunneled out of the rock at the base of the cliff and the shaft rises through solid rock to a height of 143 ft., whence it continues as a square steel structure, tied to the face of the cliff at intervals by structural braces. The elevator is electrically operated and provided with safety appliances. Switzerland has been noted for rack railways and inclined planes, but this elevator is a new method for reaching summits.



Saranac River Dam during Construction; Concrete Plant at Left.

The Saranac River Dam.

A concrete dam recently completed across the Saranac River, near Plattsburg, N. Y., has a maximum height of about 55 ft., a length of 400 ft. on the crest, and contains about 7,000 cu. yd. of 1:2:5 concrete made with Vulcanite and Ironclad Portland cement. It is located in a gorge about 400 ft. wide where the stream was diverted, and its bed was exposed by the construction of a crib coffer dam filled with rocks, sheeted on the inside and thoroughly puddled and drained by four 8-in. centrifugal pumps. The rock forming the sides and bottom of the gorge is in approximately horizontal strata, but is very much broken so that a large amount of loose rock had to be removed and the bottom excavated to a considerable depth in order to secure sound solid footings for the dam foundations. The rock blasted in rectangular blocks which were removed and piled on both sides of the bank, some of it being afterwards crushed for the concrete and some of it bedded in the latter in cyclopean masses.

The rock was handled principally by a guyed derrick at each end of the dam. The masts of these derricks were 75 ft. high and their booms being spliced to a length of 100 ft. commanded a large portion of the dam. A third guyed derrick was set up near the concrete plant and all of them were equipped with Lidgerwood hoisting engines and boom had swinging gears. They were used to build the coffer dams and assist in their sinking, to remove the stones and pile them on shore, to deliver stone to the rock crushers and to the cyclopean concrete, to build the falsework and concrete moulds and finally for the removal of the crib coffer dams after the foundations were completed.

The Saranac River is subject to occasional sudden floods which, in the contracted channel of the narrow gorge, sometimes cause the water to rise rapidly for many feet above the ordinary level; besides this there was a log jam a short distance up stream from the dam, which was liable to break at any time and sweep down the river, carrying everything before it. This would endanger any plant located near the bottom of the gorge, and it was therefore necessary to install the concrete plant on the river bank at a considerable height above the water. The plant was designed to handle very large quantities of concrete with great rapidity and was constructed on very simple principles involving the elevation of all materials at one operation to a sufficient height to enable the concrete mixing, transfer and deposition in the moulds to be effected by gravity with the minimum amount of labor or hand manipulation.

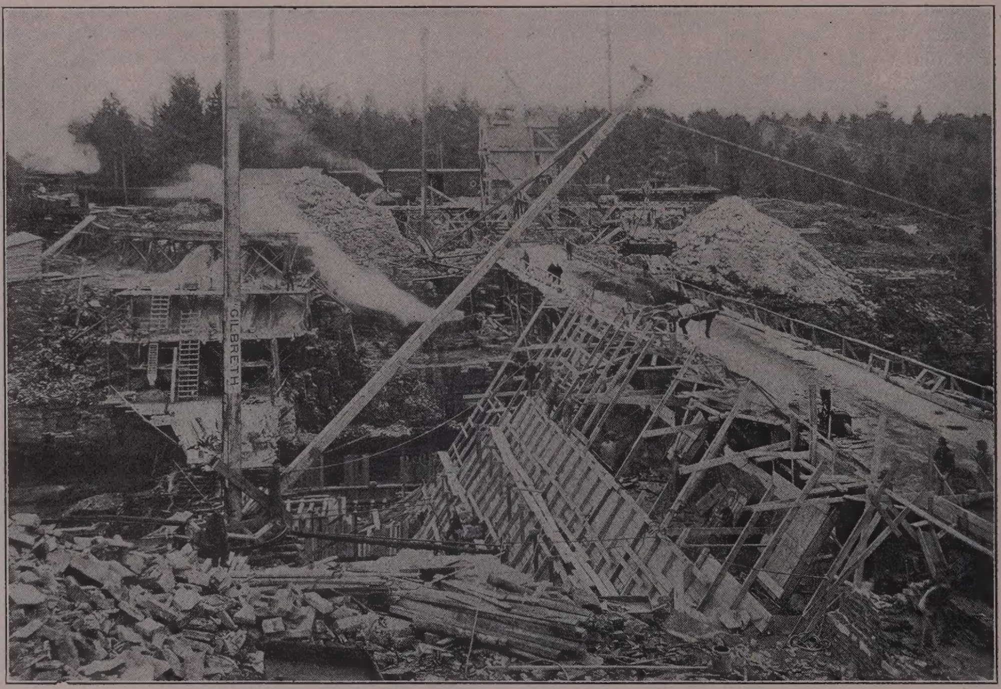
The concrete plant was located at the end of a spur track leading from the Delaware & Hudson Railroad Company's line and terminating with a Y, one branch of which was carried over a trestle at a sufficient height to enable the cars to dump sand and broken stone on storage piles alongside the concrete tower. In order to advantageously handle materials from storage to the mixing plant with a single derrick and at the same time to mix the concrete as near as possible to the point where it was used and thus avoid transportation, the concrete storage was extended beyond the edge of the river bank on heavy platforms supported by trestle bents as shown in the accompanying views.

On the upper platform of a concrete tower 46 ft. higher than the top of the dam, there were arranged bins for sand, cement and broken stone, and a man was stationed there to empty into them the contents of the buckets elevated by the derricks. On the mixing platform about 10 ft. lower down another man operated a crank which automatically fed the sand, cement and broken stone from the different chutes to the Accurate Measurer and Feeder. This could be regulated so as to supply the required proportions in any amount varying from 1 yd. in five minutes to 10 yd. in five minutes, delivered by it to the hopper of a Portable gravity mixer, with 17 rows of deflectors, which was sold by the United Concrete Manufacturing Co. The concrete was discharged from the gravity mixer into tip carts drawn by single horses down a slightly inclined platform, carried several feet above the top of the dam on a tall timber falsework trestle, and forming a working platform which commanded all parts of the dam and afforded an advantageous position for building the forms and laying the concrete.

The carts were dumped into hoppers a few feet apart, each of which was connected to a long, approximately vertical, steel tube 16 in. in diameter, mounted on a swivel and hung in chains so that it could be inclined in any direction and the foot could be raised or lowered and directed to any portion of the work included within the radius. The lower ends of the tubes were kept very close to the surface of the concrete already deposited in the mould so that when the tube was filled with the very wet concrete it was moved back and forth and allowed regular layers of concrete to flow through it to the position required.

At the ends of the dam large rocks handled by the derricks were placed in the moulds and concrete was thoroughly puddled around them. In the center of the dam, beyond the reach of the derricks, smaller stone up to about 16 in. in diameter were thrown one by one through the tubes and deposited like the concrete. The tubes being inclined sufficiently to retard the fall of the concrete and of the stones so that the impact was harmless and the attendant was able to safely control the lower end of the tube. In this way the concrete was handled entirely by gravity from the distributing platform above and the work was carried on with great rapidity and economy.

The ordinary tall falsework bents were economically constructed of green timber cut in the vicinity. In the river channel the distance between the bents was considerably increased so as to afford a much wider opening spanned by a simple wooden arch which on its top chord carried two regular intermediate bents of upper falsework. A similar low level falsework was built adjacent to the main falsework and on the top chord of its arch span carried a working platform on which materials were distributed for the construction of the concrete moulds. These were very simply made with heavy inclined posts braced to the falsework and supporting the horizontal side planks which were built up to correspond with the placing of the concrete inside. The work was executed by Mr. Frank B. Gilbreth, with an average force of about 125 men.



View of Saranac River Dam, Showing Method of Construction.

The Gatun Dam, the structure on which the proposed lock-canal at Panama primarily depends, is seriously criticised by Mr. P. Bunau-Varilla, the eminent retired French engineer who was connected for some many years with the former work at the Isthmus. In a public letter to President Roosevelt he says: "I consider such a structure a highly dangerous one in view of the softness of its mass, if one takes into account the light earthquakes which are so frequent and must be constantly expected on the Isthmus. They often cause the fall of glasses on the tables." He fears that such earth motions will cause the mass of such a dam to weaken and become liable to wash out under the great head of water behind it. While a lock canal is more exposed than a sea-level canal to damage by earthquakes, it is very remote in either case.

An Economical Reinforced Concrete Floor.

At the International Engineering Congress at St. Louis, a paper by Capt. John S. Sewell, Corps of Engineers, U. S. A., was read, in which he suggested new formulas for the design of reinforced concrete members. These were intended to combine the simplicity of purely empirical formulas with all the accuracy of more rational ones. At the meeting of the American Society of Civil Engineers on Feb. 21, another paper ("Economical Design of Reinforced Concrete Floor Systems," Proc. Am. Soc. C. E., vol. 31, p. 625) by the same author was presented, in which he gave these formulas in more detail, together with notes on their application to designs of minimum cost and the value of certain little used features of design from a fire-resisting standpoint.

The author proposes a formula in which the lever arm is a constant percentage of the depth, so that, if A = the total sectional area of steel; d = the depth of the center of gravity of the steel below the upper surface; h = a constant; T = the unit stress in the steel (assumed to be uniform over the cross-section), and M = the resisting moment of the beam, then

$$M = h\,d\,A\,T \qquad (o)$$

In any formula of this type, A must be expressed as some fraction of the area of concrete, or some other means must be adopted to avoid an excessive proportion of steel. It is one of the merits of the more complicated theoretical formulas that they contain the unit stresses in both the concrete and the steel, and thus automatically regulate the percentage of steel. Physical properties deduced from the results of such tests can undoubtedly be used as a guide to safe designs; but the author believes that more accurate, and therefore safer and more economical results could be secured by numerous tests on beams made up with varying qualities of concrete and varying percentages of steel, with a view to determining the value of the constant, h, in equation o, and of the maximum allowable values of A, in terms of the area of concrete, for various grades of concrete and steel. From the results of such experiments, a table of values could be formed, which, used in connection with equation o, would greatly simplify the work of design, without the sacrifice of any degree of accuracy attainable by the use of the more complicated formulas.

In the absence of such experiments, however, good working values for h, and for the allowable percentage of steel, can be deduced from the more complicated formulas. The point of first importance is the form of the stress-strain curve of concrete, in compression. So many tests of concrete in compression are available that the author prefers to assume an empirical curve, determined from the average results of many tests. Among recorded tests, probably none are more accurate than those reported in "Tests of Metals, etc.," at the Watertown Arsenal, for various years. Several conclusions from them seem to be warranted, as follows: The modulus of elasticity of concrete—or at least its resistance to deformation—increases somewhat with the ultimate strength. The modulus of elasticity—or the resistance to deformation—increases quite rapidly with the richness of the mixture. The stress-strain curve for very rich mixtures, especially rich mortars, does not differ much from a right line; but for leaner mixtures, including all those commonly used in practice, it differs very materially from a right line. In combining the results of many tests, in order to determine the average form of the stress-strain curve, it is necessary to combine tests having about the same ultimate strengths.

In deducing the constants used in this paper, 77 apparently normal tests from the reports of 1898 and 1899 were selected. Failure occurred in all these at from 2,500 to 3,500 lb. per sq. in. The tests were first grouped according to ultimate strength, and these groups were sub-divided according to the age and composition of the concrete. Altogether, twelve groups were thus obtained; the elastic compression, as deduced from the record—i. e., the total deformation less the set—was taken as the observed quantity in each case. The arithmetical means of the observed quantities were taken for each group; with these as one set of ordinates, and the applied loads, in pounds per square inch, as the other set, a curve was plotted for each of the twelve groups of tests. All twelve curves differed appreciably from a right line, indicating a rather rapidly decreasing modulus of elasticity under increasing loads. The area enclosed by the curves and the axes of coordinates was from one-fifth to one-fourth greater than that included between the same axes and a right line passing through the initial and final points of the curves.

With a stress-strain curve of this sort, it seems better and more accurate, in deducing formulas for the design of reinforced concrete beams, to assume a certain definite percentage of the ultimate strength of the concrete as the maximum stress to be reached when the stress in the steel is at some critical point such as the elastic limit. In designing, it is only necessary to multiply the working load by the desired factor of safety, based on the elastic limit of the steel, and then determine the section so that, under the multiplied load, the assumed maximum stresses shall not be exceeded.

After plotting the twelve curves the author measured the area enclosed by the axes of co-ordinates and that part of each curve included between the initial point and the point corresponding to 80 per cent. of the ultimate strength. The results were quite interesting; the areas varied from 55.2 per cent. to 60.3 per cent. of the rectangle enclosed by the axes and the co-ordinates of the 80 per cent. joint, the average of 77 tests being 57.2 per cent. It seems justifiable, therefore, to assume 0.57 as the area factor for the 80 per cent. portion of the stress-strain curve of concrete in compression. Several approximate but fairly accurate determinations indicated that the center of gravity of the above area could be assumed at a distance equal to 64 per cent. of the 80 per cent. ordinate above the axis of stress, i. e., the axis corresponding to the neutral axis in an actual beam.

With these quantities determined, it is possible to deduce actual working formulas. It is assumed that the beam is horizontal, and the applied forces vertical; that, within the elastic limit of the steel, sections plane before deflection remain plane after deflection; that there is such a union of steel and concrete as to make them act together; that there are no initial strains, and that the steel takes all the tensile stress, the tensile strength of the concrete being neglected.

Let E_s represent the modulus of elasticity of steel; E_c, the modulus of elasticity of concrete; T, the unit tensile stress in the steel; t_s, the elastic limit of steel; F, the unit compressive stress in the concrete; f_c, the ultimate strength of concrete in compression; all in pounds per square inch; b, the width of a rectangular beam or of a part of a floor slab, in inches; a, the sectional area of steel per inch of width; $a\ b$, the total sectional area of steel in the width, b; y_1, the distance of the neutral axis from the extreme element in compression; y_2, the distance of the neutral axis from the axis of the steel reinforcements; λ_1, the compression per unit of length in the extreme upper element of concrete; λ_2, the elongation per unit of length in the steel (assumed as uniform, and the same as that at the axis of the steel, since the cross-section of the bars is relatively small); and d the distance from the extreme element in compression to the axis of the steel; and $h\ d$, the lever arm of the stresses in the steel about the centroid of the compressive stresses.

The following equations are easily deduced:

$$y_1 + y_2 = d \qquad (1)$$

$$\frac{\lambda_2}{\lambda_1} = \frac{y_2}{y_1};\ \lambda_1 = \frac{F}{E_c}, \text{ and } \lambda_2 = \frac{T}{E_s}.$$

Therefore, $$\frac{y_2}{y_1} = \frac{T\ E_c}{F\ E_s}, \text{ and } y_2 = \frac{T\ E_c}{F\ E_s} y_1 \qquad (2)$$

$$\times 0.8\ f_c\ E_s$$

If $F = 0.8 f_c$ when $T = t_s$, $$y_2 = \frac{t_s\ E_c}{0.8\ f_c\ E_s} y_1 \qquad (3)$$

Equation 2 applies as long as T does not exceed t_s; but the values of F and E_c must always be those that correspond to each other.

Assuming $F = 0.8\ f_c$ and $T = t_s$, the conditions of equilibrium give,

$$0.456\ b\ f_c\ y_1 = a\ b\ t_s \qquad (4)$$

If M represents the moment due to the applied forces,

$$M = 0.456 \times 0.64\ b\ f_c\ y_1^2 + a\ b\ t_s\ y_2 = 0.292\ b\ f_c\ y_1^2 + a\ b\ t_s\ y_2 \qquad (5)$$

The coefficient, h, of the lever arm, hd, does not vary a great deal for widely varying stresses in the steel and the concrete, nor for widely varying positions of the neutral axis. It will be less under heavy stresses, as when the stress in the steel is at the elastic limit, than under ordinary working stresses. As a matter of safety, therefore, if it is to be used as a constant, its value should be determined for the greater stresses. Assuming that h is a constant, the value of which is to be determined from conditions existing when the stress in the steel is at the elastic limit, i. e., when $T = t_s$, it is possible to write the equation,

$$M = h\ d\ a\ b\ t_s, \qquad (6)$$

which is the same in form as equation 0.

To show the variation in the values of h, the following results, deduced from equations 1 to 5, are submitted, f_c being assumed at 2,500, and E_c/E_s at 1/15.

If $t_s =$ 35,000 lb. per sq. in. $h = 0.834$
If $t_s =$ 40,000 " " " $h = 0.846$
If $t_s =$ 45,000 " " " $h = 0.856$
If $t_s =$ 50,000 " " " $h = 0.865$
If $t_s =$ 55,000 " " " $h = 0.873$
If $t_s =$ 60,000 " " " $h = 0.880$
If $t_s =$ 100,000 " " " $h = 0.920$

Of the various forms that have been assumed for the stress-strain curve, the right line will give the greatest value of h, and a parabola with its vertex on the neutral axis will give the least. Taking an average case from those given above, as for $t_s = 45{,}000$ lb. per sq. in. (f_c and E_c/E_s remaining the same) gives, for the right line, $h = 0.865$, and for the parabola, $h = 0.84$. It would seem justifiable, from the above values, to assume a constant value of 0.85 for h, under all conditions.

Equation 6 can be used just as well for working stresses as for maximum stresses, by substituting T for t_s.

In order to complete equation 6, $a\ b$ must be expressed in terms of $b\ d$, or, what is the same thing, a must be expressed in terms of d, to insure the use of the correct proportion of steel. The writer thinks that the maximum allowable percentage of reinforcement, for various qualities of steel and of concrete, would best be determined by direct tests. In the absence of better sources of information, this percentage can be determined from formulas such as equations 1 to 5. Making the same assumptions as for the value of h, these formulas give the following results:

$t_s =$ 35,000, $a/d = 0.015$, whence $a = 0.015\ d$.
$t_s =$ 40,000, $a/d = 0.0122$, " $a = 0.0122\ d$.
$t_s =$ 45,000, $a/d = 0.0101$, " $a = 0.0101\ d$.
$t_s =$ 50,000, $a/d = 0.00855$, " $a = 0.00855\ d$.
$t_s =$ 55,000, $a/d = 0.00731$, " $a = 0.00731\ d$.
$t_s =$ 60,000, $a/d = 0.00633$, " $a = 0.00633\ d$.
$t_s =$ 100,000, $a/d = 0.00263$, " $a = 0.00263\ d$.

Other assumptions as to the form of the stress-strain curve would result, of course, in different values of a/d. The author thinks the right line gives beams heavier than necessary, and that the parabola rather inclines to the opposite extreme.

There are other advantages in the form of equation 6 besides the most apparent one of simplicity. If the maximum allowable percentage of steel is correctly determined for the qualities of steel and concrete it is proposed to use in each case, equation 6 will give a design in which both materials are worked to the safe limit; this design, from the standpoint of efficient use of material, will be the most economical. If the constants entering equations 1 to 5 are correctly determined, they will give similar results. This kind of economy, however, is not necessarily equivalent to minimum first cost, in dollars and cents. With equations 1 to 5, several tentative designs, with estimates of cost, would be required to determine the one of minimum cost. This results from the fact that the ratio of cost of steel per cubic foot to the cost of concrete per cubic foot is entirely independent of the ratio between the maximum allowable stresses of the two materials. It is desirable to express the cost in terms of the first-named ratio, and then to apply the principles of maxima and minima, if possible, so as to disclose at once the conditions leading to minimum cost. With equations 1 to 5, this cannot be done, because as soon as the materials are selected their physical qualities fix the percentage of steel, which is a constant from that moment.

In the succeeding portions of the paper the author analyzes the effect of the cost of centering, of concrete below the steel, of concrete above the steel and of the steel itself on the cost of the beam, together with the other factors which affect the problem of maximum economy. The formula he derives is

$$a = \frac{M_1}{h\ t_s\ d} = \frac{w\ l^2}{8\ h\ t_s\ d} + \frac{w'\ d\ l^2}{8\ h\ t_s\ d}, \qquad (7)$$

where l is the span in inches, w the total line load per linear inch in pounds, w' the weight of concrete in pounds per cubic inch, and M_1 the total bending moment on a beam of unit width.

In actual practice, Capt. Sewell would use $d \div p$ instead of a unless the maximum allowable value of a, as deduced from experiment or from equations 1 to 5, should be less than d/p; in which case the maximum allowable value of a would be used. By p is designated the ratio of the cost of steel per cubic foot to the cost of concrete per cubic foot.

The only equation required for designing would then be equation 7. For a would be substituted its proper value, in terms of d, and the equation would be solved for d. For a beam of width, b, it is only necessary to make very obvious changes in the formula. The value of a follows, when d is known. If great accuracy is not necessary, an approximate value for the dead load can be assumed; the total moment is then a constant, and the equation giving the value of d will be a pure quadratic, instead of an adfected one, as in the other case. The question is at once suggested by the results above deduced, whether, in the case of steel of high elastic limit, in which the maximum allowable value of a is much less than d/p, greater economy could not be attained by reinforcing the concrete against compression. Capt. Sewell's analysis shows that, when $t_s = 100{,}000$, it is cheaper to use lower reinforcement only. If this is true for this value of t_s, it is certainly true for any other value likely to be used in practice. It is advisable, therefore, to use double reinforcement only when the conditions of the problem restrict the value of d, or when it is very important to reduce the dead weight to a minimum. When only lower reinforcement is used, and $t_s = 100{,}000$, the value of d is about one-third greater than when double reinforcement is used. This will make some difference in the actual live load capacity, if m is assumed as a constant. If the live load is very small, as compared with the dead load, this may change the relative costs, for a given live load capacity, so as to make the double reinforcement more economical; but if the live load is relatively large, the single reinforcement will be more economical. In practically all cases that would ordinarily occur, the single reinforcement will be the cheaper, by at least 20 per cent.

Hitherto, it has been assumed that the beam was to be reinforced against what may be termed the flange stresses only, and the discussion applies, of course, to the section where m is a maximum;

but other stresses exist in reinforced concrete beams, corresponding to the web stresses in steel beams. For simplicity they will be referred to as web stresses.

Assuming the beam to be uniformly loaded, the ideal web reinforcement would consist of a multiplicity of relatively small members attached to the horizontal reinforcement, and inclined both ways from the center of the span, at an angle of 45°. The attachment to the horizontal reinforcement should be independent of the concrete, should permit no lost motion between web and flange reinforcement, and should be strong enough to develop the strength of the former. The spacing should vary from the center to the ends, decreasing in proportion to the increase in the web stresses. In any case, the sum of the horizontal components of the stresses in all the web members in each half of the beam should be at least equal to the maximum stress in the flange reinforcement. The web members should all extend entirely to the top of the beam.

It is not worth while to consider either web members or variations in d, in designing the section of maximum moment, except that the value of M may be written as a function of d, if it is desired to avoid guessing at the dead weight. After a little experience, however, the designer will be able to guess the dead weight with sufficient accuracy, and in that case he will have only a pure quadratic to solve—otherwise he will have to solve one containing both the first and second powers of d.

All that has gone before is applicable only to rectangular beams and floor slabs. No extensive system of reinforced concrete floors can be economically designed, however, without the use, either of rolled steel beams, or else of reinforced concrete ribs, forming, together with a portion of the floor slab in each case, what is practically a T-beam.

It is necessary, therefore, to consider the economical design of such sections as this. In Capt. Sewell's St. Louis paper he presented formulas for T-beams modeled after those deduced by A. L. Johnson. In applying these formulas to particular cases, the total allowable width of flange was generally found to be between $3b$ and $4b$, b being the thickness of the web. He thinks conservative practice would confine this width to $3b$. By the assumptions as to the stress-strain curve assumed in this paper, and those made in the St. Louis paper as to the distribution of stresses in the flange of the beam, the average stress in the compressed part of the concrete of a T-beam may be taken as not less than 0.44 f_c, under the loads producing the maximum stresses assumed in deducing the formulas.

The web stresses, in practice, are quite as important as the flange stresses. The web of a plate girder, and the web members of a bridge truss, often demand much more attention than the flanges and chords. This is equally true of reinforced concrete girders and beams. If it is bad practice to count upon the tensile strength of the concrete in the lower part of the beam, it is equally bad practice to count upon it in the web.

About August, 1904, the author had to design some rather important long-span girders for the War College Building at Washington Barracks, D. C. He had, nearly two years before, become convinced that not only ought reinforced concrete beams and girders to be designed with web reinforcement, but that the tensile web members ought to be arranged at an angle of 45°, and firmly attached to the horizontal reinforcement, without the possibility of lost motion, so that the horizontal components of the tensile web stresses could be transmitted into the horizontal reinforcement, without depending on the surrounding concrete; in other words, that concrete should no more be relied upon for connections than for resisting tensile flange stresses. Previous to the time when the War College work was designed, the writer had analyzed the web stresses by analogy with a Pratt truss; but study of the War College problem made it apparent that the double intersection Warren girder was a better analogy, and the author has used it since that date.

It is fairly well established that, under temperatures of from 800° to 1,000° Fahr., cement which has set begins to lose its water of crystallization; as this change progresses the strength is impaired. If the fire lasts long enough the lower part of the concrete in a floor system is completely ruined, and generally comes off, exposing the steel; if the fire still continues, collapse, in ordinary designs, speedily follows. The exposure of the steel is undoubtedly greatly accelerated by the existence of severe stresses in the concrete immediately surrounding the steel, in all cases where attached web members are not used. Where they are used the damaged concrete, having no structural duty to perform, will hang on longer, and at least protect the steel; even after it comes off, the structure will collapse only after the steel becomes hot enough to have its tensile strength seriously impaired.

Even if collapse does not occur—in fact, even if the steel is not exposed at all—in cases where attached web members are not used, if the concrete has been dehydrated to any appreciable depth, nothing short of rebuilding will constitute adequate repairs. The damaged material must come off; on it, and its bond with the concrete above, depended the ability of the steel to transmit its stresses into the upper part of the beam. There is no known method of replacing the damaged concrete with new material, and of securing a bond between the new and the old, anything like as strong as the original cohesion.

If, however, attached web members are used, there is no necessity, as far as strength is concerned, for any concrete below the horizontal reinforcement at all; even if the concrete is seriously damaged as high up as the neutral axis, the floor can be supported by shores, the damaged concrete removed, and new material substituted for it; the bond between the new and the old material, with the assistance derived from the steel, will be sufficient to hold the new material in place so that it can protect the steel against fire and corrosion, and resist the compressive web stresses, quite as well as in the first instance. In other words, adequate repairs are possible without complete renewal.

A point ordinarily of vital importance in the practical execution of work is the bond between the floor slab and the part of a beam or girder below it. It almost always happens, as a matter of convenience and economy in execution, that the concrete for that part of the beam below the slab is first deposited, and then allowed to set for quite a while—several hours, or even a whole day—before the concrete for the slab is deposited. This is a matter of secondary importance if properly designed and rigidly attached diagonal web members are used, otherwise it is one of serious importance, and fraught with great danger. There is good reason to believe that many failures in practice have been due to this one condition, and that many structures now standing would fail from the same cause under loads only slightly greater than their working loads, should they ever be so tested.

In this connection it may also be pointed out that the use of attached web members, extending to the top of the beam, makes it possible to adopt a concrete for all parts below the neutral axis, for its fire-resisting qualities chiefly, and one for the parts above the neutral axis, for its compressive strength. The two qualities seem not to be combined, as a rule, in the same concrete. Well-made cinder or clinker concrete is much more fire-resisting than stone or gravel concrete, but it is not nearly as strong. It is more than strong enough, however, to resist all compressive web stresses, and this is the only necessary structural duty of the concrete below the neutral axis, if attached web members are used.

If the author's deductions, from the results of tests and the theoretical study of the subject, as partly outlined in this paper, are well founded, the following principles may be stated, including some that are the result of executing reinforced concrete work by hired labor, under circumstances demanding the utmost economy.

1. In designing the section of maximum moment, the maximum economy, in dollars and cents, will result when $A = b d \div p$; if, by equations 1 to 5, this gives too much steel, then the maximum allowable percentage of equations 1 to 5 will give the greatest attainable economy, in dollars and cents.

2. It is not worth while to consider the variations in the applied moment, due to variations in d, unless extreme accuracy is desired, or unless minimum weight is desirable; but an allowance for dead load must be included, in computing the value of M, in any case.

3. For all girders and beams—and for all flat slabs, if the best results are sought—there must be, in addition to the main horizontal reinforcement, web members, arranged along the lines of tensile web stress, and rigidly attached to the horizontal reinforcement; they must be spaced so that their aggregate area of cross-section will increase in proportion to the increase in the total web stresses, as the abutments are approached; some web members should be added as counterbraces, according to circumstances.

4. The adhesion, or bond, of that portion of each web member traversing the compressed part of the concrete, should be sufficient to develop the strength of the member, and the attachment of the member to the horizontal reinforcement should be equally strong. Each horizontal bar should have its own set of web members. Mechanical bond should be used in the upper part of the web members, if there is the least doubt as to the adhesion.

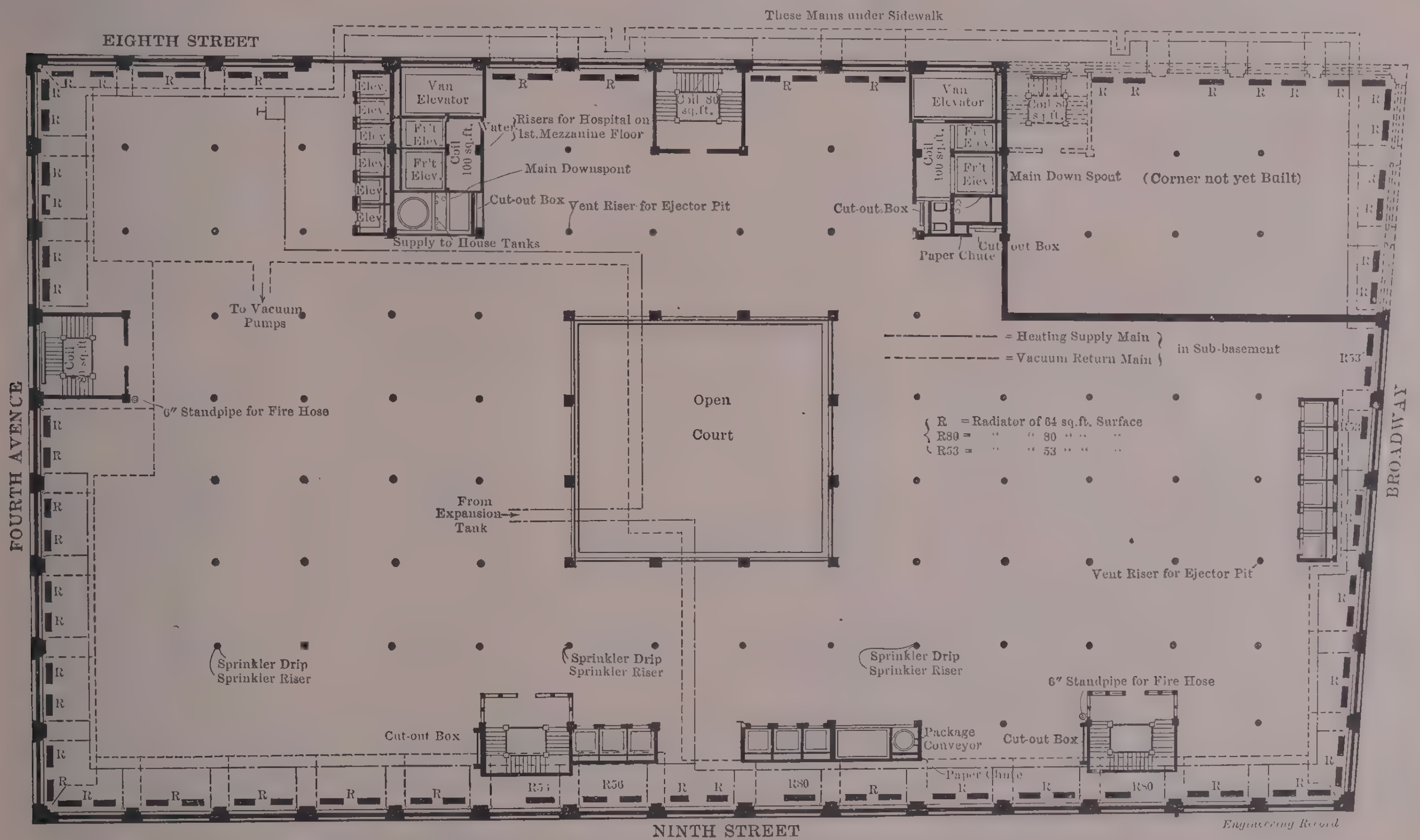
5. Cheap and easily attached clips, forming small feet, should be used to hold the horizontal bars at the proper distance above the centering; these bars should be of rounded section, as nearly circular as possible, so as not to cause unnecessary shrinkage stresses in the concrete, and so that the wet concrete can be readily made to flow under them. This will give a better result, at less expense, than the current practice of depositing first a thin layer of concrete, and then bedding the steel in it.

6. As reinforced concrete becomes monolithic in setting, the girders, beams, etc., will act as continuous girders, whether or not that is desired by the designer. This condition might as well be accepted, and reverse reinforcement used at the proper points, to avoid unsightly and often dangerous cracks, if for no other reason. If this is done it is entirely permissible to reduce the bending moment at the middle section very materially, thus saving some steel in the main reinforcement. The proper distribution of web members in this case requires special attention.

Wireless Telegraphy has been in regular use between New Orleans and St. Louis since Feb. 28. On that day the American DeForest Wireless Telegraph Co. opened its New Orleans station and messages have been sent to and from it every night. It was opened for the purpose of communicating with ships in the Gulf of Mexico and with stations at Mobile, Southwest Pass, Galveston, Pensacola and Key West. At night the station can also communicate with Havana, St. Louis and other inland points that are furnished with high-powered equipments for long-distance transmission.

Mechanical Plant of the New Wanamaker Store, New York.—II.

Heating System.—The new store building, above the main floor, is heated entirely by direct radiation, with the exception of the music hall, occupying a portion of the second, third and fourth floors, in which an indirect system will be used. The main floor will be heated by direct radiation, supplemented by indirect, in connection with the ventilating systems, while in the basement and sub-basement, indirect radiation will be depended upon almost entimely. The system is operated by exhaust steam from the steam-using machinery in the power plant, in the usual manner, the Webster system of steam circulation being used to avoid back pressure. It is a system of considerable magnitude, involving the heating of 14 floors, 182x328 ft. in size, and two basements amounting to nearly 1,000,000 sq. ft. of floor area, for which over 100,000 sq. ft of radiation are installed, including the tempering coils of the ventilation systems; in addition the heating system of the old Wanamaker store across the street is also now operated from this power plant. The equipment is designed to maintain a temperature from basement to attic in the new building at 70° F. in zero weather, with a steam pressure of not over 3 lb.



Typical Floor Plan of New Wanamaker Store Building Showing Distribution of Direct Radiation.

The heating system originates in the expansion tank in the boiler room, to which all exhaust lines from the engines and pumping machinery of the power plant are led, as described in the issue of Feb. 24. This tank, which is a steel cylinder 25 ft. long and 6 ft. in diameter, serves as a combined receiver, muffler tank and separator for removing oil from the exhaust, and in its bottom 12 to 14 in. of condensation is maintained, which assists in the separation of oil. The supply from this tank to the heating system is through three systems of distributing mains on the ceiling of the sub-basement, one of which supplies the heating risers on either side of the building, and the other the tempering and reheating coils of the blower systems. For the latter there is a 10-in. main which leads across the engine room to the fan-room, where it branches with an 8-in. line to blower systems 1 and 2, and a 9-in. line to systems 3 and 4. The north or Ninth St. side of the building is supplied by a 12-in. feeder from the expansion tank, which delivers to a main extending along the outer edge of the building and half of both the Broadway and Fourth Ave. fronts, supplying a heating riser at each wall column. The Eighth St. half of the building is fed by a 15-in. line, which is carried through the boiler-room to the south wall line, where supply connections are similarly made to risers at each outside building column; this main also supplies a 6-in. riser in each of the two pipe shafts upon this side of the building, which are carried up to supply the special heating equipment for the attic floor and tank houses upon the roof, to which reference will be made later.

All radiation is supplied on the two-pipe system, for the operation of which there are supply and return risers carried up around the outside of the building. For this purpose there are in all 83 risers extending from the sub-basement to the 13th floor, 44 of which are for the supply and 39 for return of condensation. The supply risers are, for the greater part, of 4-in. pipe, although there are also 3, 2½ and 2-in. risers in portions of the building where less radiation is to be supplied. The return risers are of 2-in. pipe for the greater part, although in some cases 1½ and 2½-in. pipe is used. These riser lines are anchored to the building framework at the basement and 7th floor, with expansion loops of the usual swiveling U-loop form at the third and twelfth floors. The return risers have at their lower ends Webster thermostatic return valves which deliver to a system of collecting mains, extending entirely around the building and uniting at the vacuum pumps of the Webster system.

The radiation for the heating of the upper floors is distributed around the outside of the building only, 26-in. two-column radiators being located beneath the windows on all sales floors; exceptions to this are to be noted upon the first floor, where, owing to show-window arrangements, all radiators have been located on the main floor opposite street entrances; the second floor, where special arrangements of small piano rooms necessitated different distributions, and the attic, or fourteenth floor, where all radiation is disposed in skylight coils. The distribution of radiation is shown in the accompanying plan of a typical upper floor, including the projected uncompleted section at the southwest corner, which is to be added in the future; this plan shows also diagrammatically the arrangement of connections of the supply and gathering mains in the sub-basement to the supply and return risers.

The radiation is disposed nearly uniformly in close proximity to the outside window areas on all sides of the building. There are in general two radiators per wall panel between windows, each having 64 sq. ft. of heating surface, making 128 sq. ft. per panel of 20 ft. between columns. There are exceptions to this in spaces back of elevator shafts and stair wells, where single 80 sq. ft. radiators are in some cases used and in others two radiators of 50 to 60 sq. ft., but in general there is about 6 sq. ft. of radiation per lineal foot of exterior wall per floor. In each wall panel containing two 64 sq. ft. radiators there are three windows, each 45x110 in. in size, giving thus approximately 110 sq. ft. of glass exposure which the radiation must counteract. Each typical floor has, where not altered by subdivision into smaller rooms or other changes, 81 radiators, presenting a total effective heating surface of 5,160 sq. ft. There are also 640 sq. ft. disposed in pipe coils and radiators in vestibules, toilet and auxiliary rooms.

The attic floor is devoted to workshop purposes, where large floor spaces and ample lighting are important, such as the carpet cutting and sewing department, and it is accordingly surmounted by three very large skylights and eight smaller ones, in which considerable radiation was necessary. The larger skylights are, respectively, 59x83 ft., 58 ft. square and 39x62 ft., the first covering the carpet-cutting floor and the second the central open court rising through the building. Each skylight has four sets of heating coils beneath the edges of the glass, the largest having four coils with 460 sq. ft. of heating surface; those in the skylight over the open court are 360 sq. ft. per coil, and those in the third skylight 326 sq. ft. per coil; the total radiation for these lights is thus 4,584 sq. ft.

Of the eight smaller skylights four are about 16x19 ft., and the other four 18 ft. square. Each has two coils, those of the first four with 198 sq. ft. of radiation each, or 396 sq. ft. per light, while the coils in the others are each of 210 sq. ft., or 420 sq. ft. per light.

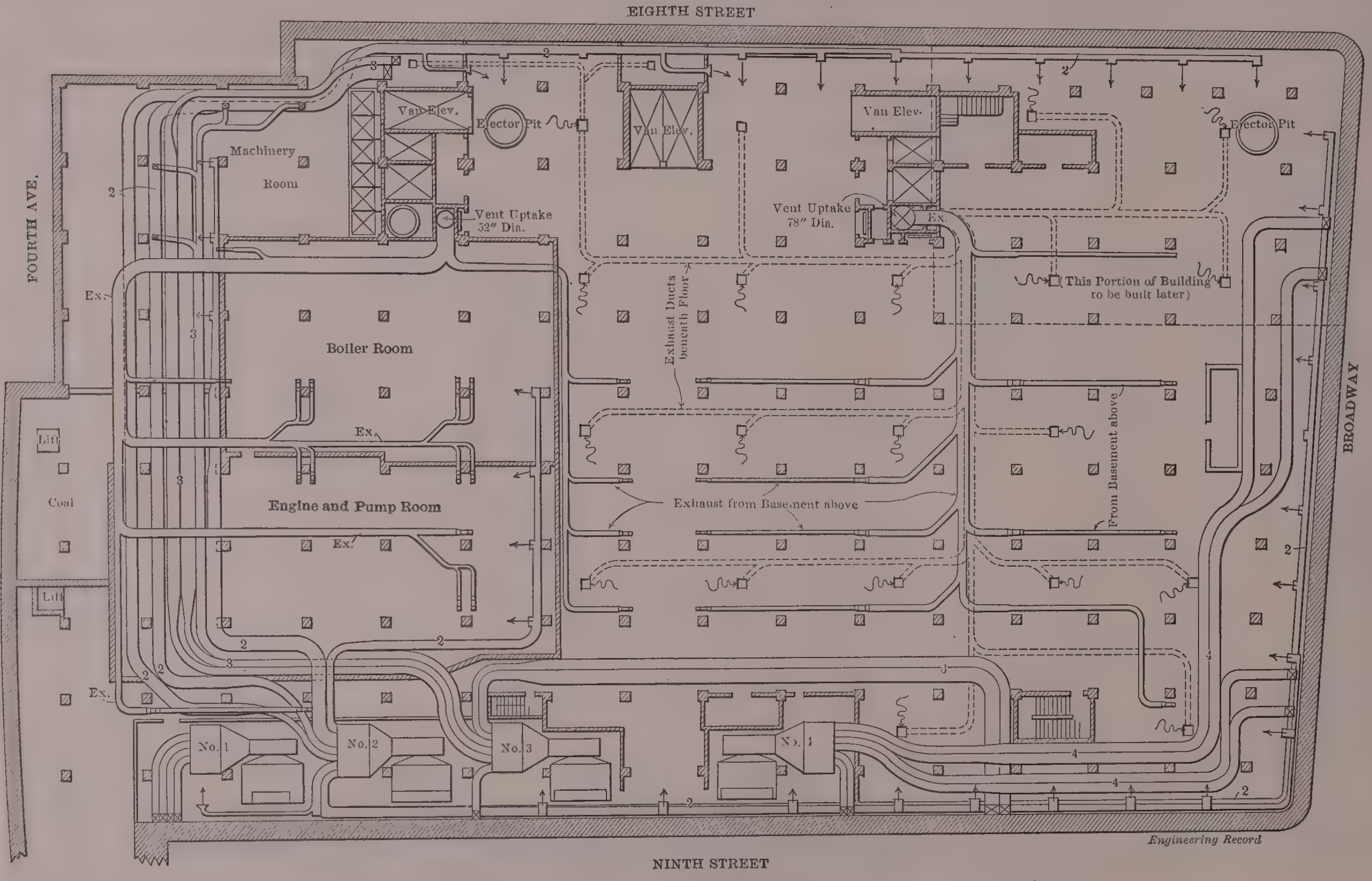
There are in all, therefore, 3,264 sq. ft. of radiation beneath the smaller skylights, which, together with the 4,584 sq. ft. in the three larger ones, gives 7,848 sq. ft. of radiation by which the attic floor is heated. These coils are in all cases of 1¼-in. pipe. They are supplied through the two special 6-in. risers in the pipe shafts from the sub-basement, above referred to, and condensation is returned by 3-in. lines paralleling them. These risers also supply radiation in the large 25x47-ft. tank houses upon the roof, one over each of the pipe shafts. Each house has 12 radiators arranged in the four corners at three different levels, the total radiation per house being 624 sq. ft.

Positive steam circulation at atmospheric pressure is effected by the Webster vacuum system, for which two return pumps have been installed in the boiler-room to remove condensation and air from the return lines and risers. These are 12x18x18-in. Knowles duplex steam pumps, which draw from the return systems through a large return header or tank at the rear of the boilers and deliver the condensation, freed from air and vapor, into open feed-water heaters for heating, filtering and return to the boilers. The vacuum pumps are located immediately at the rear of the feed-water heaters, while the return header is nearby in the space at the rear of the first battery of boilers. There are six return lines leading to this return header, which are kept entirely separate, as follows: A 5-in. line from the return risers in the northwest quarter of the building, a 7-in. line from all of the remaining return risers of the building, including the special line from the skylight radiation in the west half of attic, a 5-in. line from the tempering and reheating coils of the indirect systems, including the special line from radiation in the east half of the attic floor, a 3-in. return from the hot-water heaters and refrigerating machinery, a 2-in. return from the auxiliary radiator equipments on the first floor, and a 1-in. line to return condensation from a special steam line carried to the roof for thawing down-spout heads in winter. The pumps deliver first to a small elevated expansion tank above them, which has a vent connection to the vapor line leading from the blow-off tank to the roof; here the condensation returns are freed from vapor and air, and thence flow by gravity to the feed-water heaters.

The supply and return piping and all connections are concealed on all of the retail floors up to the ninth, above which, in storage and packing departments, it is run open in the usual manner. All piping for the heating system, both supply and return, is installed with screwed flanged fittings on all lines 3 in. in size or larger. All horizontal supply lines are graded with the flow of steam for drainage, the slope ranging from ¼ in. in 10 ft. for large mains to 1 in. in 10 ft. for the smaller lines. The American radiator was used for this installation in both the double (Perfection) and three-column (Rococo) types. The valves used in the piping system were supplied, as well as all pipe flanges, by the Crane Company, with the exception of at radiator connections, where Jenkin's valves were used.

Ventilating Systems.—Ventilation is to be effected mechanically on the main floor, in the basement and sub-basement, in the music hall and in the kitchen upon the ninth floor, and in the remainder of the building by an open shaft 58 ft. square in the center of the building which rises from the main floor to the roof; all floors of the building open directly into this court, which is surmounted at the roof by a full-size skylight with ventilators of ample size. For the ventilation service there are nine fan systems, five for tempered fresh-air supply and four for exhaust. The former are located in the sub-basement and the latter in the attic, with the exception of two equipments for the music hall, which are located on the fourth floor above the stage. For these installations extensive systems of duct work were installed, the arrangements of which are shown in the accompanying drawings.

A novel feature of the fresh-air supply systems for the basements and main floor is the use of air-washing apparatus for the purification of the air and regulation of its humidity, one of the first air-washing installations in New York City. Owing to the impossibility of carrying the intake shafts for these systems up to the roof line to secure the cleanest possible air supply, the radical method was adopted of taking in the air through sidewalk gratings, where quantities of dust, dirt and refuse are inevitably encountered, and subsequently passing it through air-washing apparatus for cleansing and regulation of humidity. The arrangement of these systems in the sub-basement, together with their delivery systems, are shown in the accompanying sub-basement plan. The fan systems are arranged in a row in a fan room at the northeast corner of the building beneath the sidewalk. The principal service for which these systems were installed is to supply tempered air in large quantities at all street entrances and vestibules in order to effect the heating of the main floor through these sources. All of these systems, with the exception

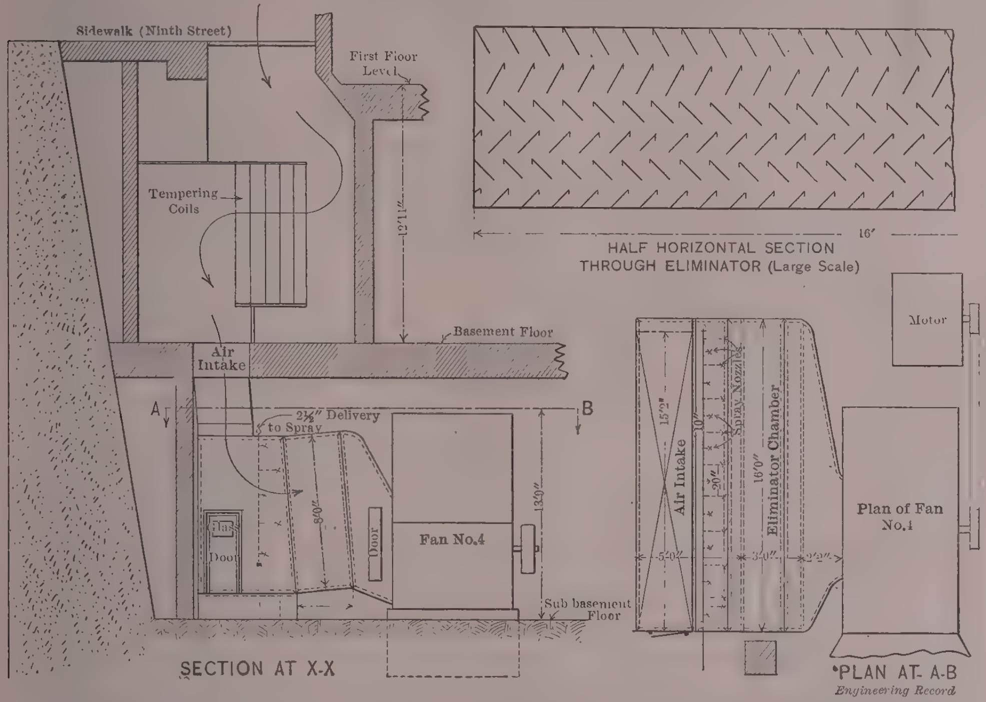


Arrangement of Blower Systems and Ductwork in Sub-basement, Wanamaker Store Building.

of No. 2, are devoted almost entirely to this supply; system 2 supplies air to the sub-basement and the mechanical plant.

These systems have their intakes through gratings in the Ninth St. sidewalk above them, as shown in a detail view of the air-washing equipment. The air is drawn by the fan, in each case, downward through a tempering coil and thence through air washing apparatus as shown. Each system has in addition to the tempering or preheating coil, a reheating coil in the fan delivery, the latter having automatic temperature regulation. This arrangement permits the humidity of the delivered air to be adjusted at almost any point desired, which is accomplished by setting the preheating coil to heat the entering air to the temperature at which it will take up the required amount of moisture in passing through the air wash, after which it may be reheated to any desired delivery temperature.

The air-washing equipment consists of a spray chamber in which the air is drawn through a sheet of water spray before entering the fan, an eliminator between the spray and the fan preventing water being carried mechanically into the fan or delivery system. The spray nozzles are close together in staggered rows, as indicated in the detail view of system 4. Each system has six horizontal rows of pipe carrying these nozzles; the rows are 18-in. apart vertically, each casing being 8 ft. in height, variations in capacity for the various systems being secured in length of cross-section. On each horizontal pipe the nozzles are connected at intervals of 20 in., being staggered so that there are vertical rows of spray nozzles every 10 in. entirely across the washing chamber. The nozzles are of a side spray type, so that all deliver a sheet of spray at right angles to the line of flow of the air, the result being that the air cannot pass through the chamber without coming in contact with the spray. The nozzles have, however, a lever attachment so that the spray attachment may be opened for a direct stream if necessary, in order to clear out any obstruction that may be carried into them with the water. The levers for all nozzles on each horizontal row are connected to a rod with a handle outside the casing, so that they may be operated from outside when necessary, a glass in the door in the casing facilitating examination of the interior.



Section Under Sidewalk at Blower System No. 4, Showing Intake and Air-washing Apparatus.

Between the spray chamber and the fan there is in each case an eliminator or water separator, to arrest the water carried along mechanically with the air entering the fan. Each eliminator has six rows of inclined baffle plates, as indicated in the half horizontal section in the drawing of the air wash apparatus; these baffles consist of vertical strips of sheet copper 6 in. wide with a hook edge on the side toward the fan, to engage particles of water coming in contact with the strips, due to the zigzag course of the passing air, and thus remove them from the air. In each system the eliminator is of a height and width equal to that of the spray chamber and is 3 ft. in depth, but is inclined slightly backwards toward the spray chamber, which both facilitates the separation of water from the air on the baffle plates and also the drainage of water from the latter back to the catchbasin beneath the spray chamber. Each system is built of 16 oz. copper on a frame work of 1½x1½x⅛-in. angle iron. The catchbasin beneath the spray is of ¼-in. boiler iron, 5 ft. in width and 15 in. deep in each case, which serves as a storage and supply tank.

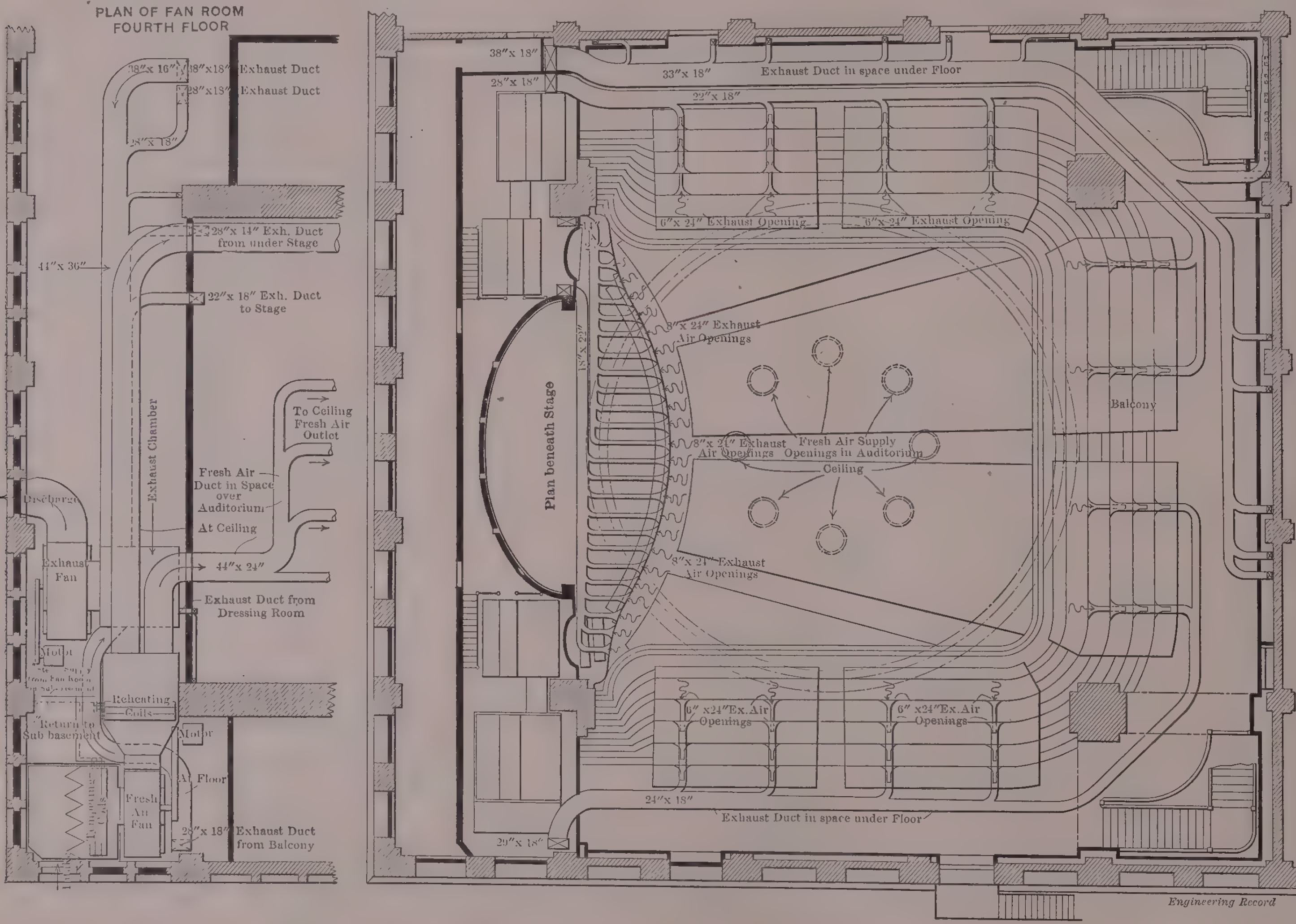
The water for the nozzles is used over and over continuously for a number of days. Although large quantities of dirt and rubbish of all forms are drawn in through the sidewalk intake, it is removed by the air wash to the catch basin, where it settles, and it is found that the water may be used repeatedly by means of effective strainers in the pump supply. The water is circulated by centrifugal pump for each air wash, which is belt driven by a Crocker-Wheeler electric motor. The pump in each case takes its suction from the catchbasin through a series of coarse and fine strainers, returning the water to the system through a line above the spray chamber which connects downward to the headers at either end of the nozzle supply pipe. System 1 has 42 nozzles, each of which has a discharge capacity of 4½ gal. per minute, thus requiring, when in operation, 189 gal. per minute. System 2, which has nearly double the capacity of No. 1, has 68 nozzles, requiring a circulation of 225 gal. per minute. Systems 3 and 4 have 58 nozzles each, requiring 261 gal. per minute. The centrifugal pumps for this service are driven by motors of 2, 6 and 5 h.-p., respectively. The air-washing apparatus used in the systems is the Acme system, installed by Thomas & Smith, patentees, New York, as sub-contractors to Gillis & Geoghegan.

Fan system 1 is devoted entirely to the supply of air to vestibules at the Fourth Ave. end of the building, in which there are twelve outlets, requiring together 32,000 cu. ft. of air per minute. System 2, which is confined to the sub-basement fresh-air supply, has four outlets in the fan-room, eleven in the engine and pump-room, and twenty-seven in the main room of the sub-basement, which is devoted to packing and shipping purposes for the store service, this system requiring 62,050 cu. ft. of air per minute. System 3 supplies air in the sub-basement, basement and vestibules, there being five outlets in auxiliary rooms, and four in vestibules on the Eighth St. side, while the remainder of the delivery supplement system 2 with 27 delivery outlets in the packing and shipping section of the sub-basement. System 4 is devoted to the supply of vestibules on the Ninth and Broadway portions of the building, which require eighteen outlets with a total capacity of 48,000 cu. ft. per minute. The fans are of the three-quarter steel-plate housed centrifugal type, built by the American Blower Co. Each is driven by a General Electric direct-current motor, with Cutler-Hammer starting rheostat equipments, which were installed in 25, 60, 45, and 45 h.-p. sizes. All connections from blowers to ductwork are tubes of 6-oz. duck to prevent vibration of the delivery ducts.

The reheating coils of each system are as stated, equipped for automatic temperature control, Powers thermostats being used in the delivery ducts, from which diaphragm valves are operated on the steam inlets to the heating stacks. Each system is equipped with a preheating or tempering coil, in order both to raise the temperature in winter to avoid freezing in the spray chamber and to permit of regulation of the humidity. These tempering coils have 1,700, 2,800, 2,400 and 2,800 sq. ft. of radiation for the systems, 1 to 4 respectively. The reheating coils for systems 1 and 4 are of the same sizes as their tempering coils, while those for systems 2 and 3 have surfaces of 560 sq. ft. each.

The exhaust systems provide for the removal of air from the basement, sub-basement and kitchen on the ninth floor, there being three systems for the former, operated by a disc and two blower exhaust fans upon the attic floor, and a separate exhauster for the kitchen. There is also a system of exhaust ventilation for the toilet rooms throughout the building. Gathering ducts lead from the various inlet registers in the basement and sub-basement, as shown in the sub-basement plan, to uptake ducts in pipe shafts in two sections of the building, that for the east section, which is adjacent to the smoke stack, being 52 in. diameter while that for the west section is 78 in. There are numerous floor openings in the basement to which the gathering ducts are lead upon the ceiling of the sub-basement, as shown in the sub-basement plan. The sub-basement exhaust is taken from beneath the floor, the gathering system duct work for which was laid in the concrete floor, as shown by the dotted lines. The latter ducts are of circular cross-section, and formed of black iron pipe around which the concrete was poured direct in the construction of the floor. The basement exhaust registers are in all cases 12 x 30-in. openings, while those in the sub-basement floor are 27 in. square. On the basement floor there are 64 exhaust openings, each of which removes 800 cu. ft. per minute, while in the sub-basement there are 22 openings removing 1800 cu. ft. per minute each. For the east exhaust system there was installed an attic fan in the attic of 50,000 cu. ft. capacity, while that for the west system is of 35,000 cu. ft. capacity. These exhaust fans deliver directly through air caps or hoods immediately above them on the roof, which are of heavy copper construction. The east fan is driven by a 40 h.-p. motor while that for the west system has a 25 h.-p. motor, both of General Electric make. The disc fan exhausts from the boiler room and is operated by a 10-h.-p. motor. The toilet room exhaust system is operated by a 70-in. exhauster, run by a 5-h.-p motor.

For the ventilation of the kitchen, a special system has been installed consisting of an exhaust gathering system connecting to a main vent riser which is carried up to the attic floor to a fan discharging through an outlet hood upon the roof. The fan is a 140-in. A. B. C. blower rated at 20,000 cu. ft. per min. and is driven by a 25-h.-p. General Electric motor. The main vent riser duct for this system is of 30x78-in. section and is carried to the attic in the open court in the center of the building. There are four branches in the kitchen gathering system, one a 20x24-in. duct to the range hoods, two 20x26-in. lines and the fourth an 18x20-in. duct, into which the exhaust inlet openings are made. A feature of this system is an automatic by-pass in the main vent riser duct at the attic floor which, in case of fire in the duct, will cause the by-pass to open and discharge directly into the outlet hood; this by-pass has a fusible link which normally holds the damper in such a position as to admit the vent to the exhaust blower, but upon melting, due to excessive heat, the link permits the damper to drop and by-pass the fan.



Details of Heating and Ventilating Equipment of Music Hall, New Wanamaker Store.

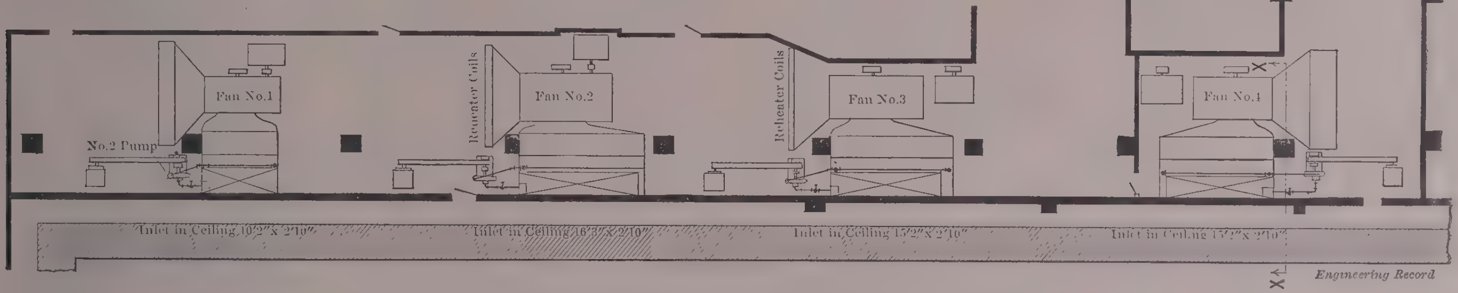
Music Hall Ventilation.—An interesting feature on the second floor is a large music hall for entertainments, recitals, exhibitions of pianos and other musical instruments, which introduced problems in ventilation similar to those encountered in theatre buildings. The hall has a total seating capacity of about 1,200 and occupies a space 110 ft. square, at the Fourth Ave. and Ninth St. corner of the building upon the second, third and fourth floors, the volume enclosed in the auditorium being nearly 250,000 cu. ft. The stage, 58 ft. wide by 22 ft. deep, is located at the Fourth Ave. side of the hall, behind which there is an enclosure 22 ft. in depth for dressing rooms and auxiliary purposes, and on the three other sides there are balconies at the third floor level, each 25 ft. in width. The space occupied on the fourth floor was required by a special arrangement of building framework, 6 ft. girders of 60 ft. span having been located over the auditorium to carry the building columns above and provide for an unobstructed space below; sufficient room was found at the rear for the heat- and ventilating equipment for the auditorium below.

The auditorium of the hall is equipped for indirect heating and ventilation on the downward system, the arrangement of apparatus and duct work for which is shown in the fourth floor and balcony plans. All fresh air is delivered to the auditorium through eight large outlets in the domed ceiling, while the exhaust is taken from many small openings in the front of the stage just above the floor, under the balcony and through the fronts of the tier risers in the balcony. The system is designed to supply approximately 30 cu. ft. of air per minute per person for the full seating capacity, while the exhaust system removes practically the same volume, but by means of distributed openings serves to make the ventilation effective in all portions of the hall. The fresh air supply system has an air filter and tempering and reheating coils, the latter with thermostatic control. The fresh air supply system is very simple, having a single 24x44-in. duct from the supply fan in the corner to the area over the ceiling of the auditorium and branches to the eight downward openings through the top of the domed ceiling. This system is designed for a normal delivery capacity of 34,800 cu. ft. per min., giving thus a delivery velocity through the trunk duct of 4,750 ft. per min. The velocity is reduced in the branches to the various delivery outlets to 2,500 ft. per min. or less, and the outlets themselves are all of conical shape, expanding downward to circular openings, 42 in. in diameter, in order to still further reduce the velocity; each outlet delivers 4,350 cu. ft. per min. at a velocity of about 450 ft. per minute.

The fresh air supply fan is a 9-ft. full-housed steel-plate blower which has an intake through a filter room in the corner of the building and delivers through a reheating chamber to the delivery duct. This fan is belt driven by a 30-h.-p. General Electric motor and at the normal speed of 180 r.p.m. delivers 34,800 cu. ft. per min. at a pressure of 0.53 oz. The system has tempering coils on the inlet side of the fan and reheating coils on the delivery, the latter being controlled from the temperature of air delivered by the Powers system of heat regulation. For the steam supply to these coils, there is a 6-in. riser carried up from the fan coil main in the sub-basement and a 3-in. return for the Webster vacuum return connection. The tempering coils are three sections of No. 40 A. B. C. stack with 2,100 sq. ft. of heating surface, while the reheating coil has three sections of No. 31 A. B. C. stack with 1,200 sq. ft. of surface.

The fresh air intake is through a settling chamber, 12 ft. square, in the corner of the building which contains an air filter of the cheese-cloth type and the tempering coils, a window on the Ninth St. side serving as the air inlet. This air filter consists of ten sections of screen each 30 in. wide and 12 ft. high, presenting thus a total filtering surface of 300 sq. ft., and having filtering velocity of 116 ft. per min. when the fan is operated to the full capacity. The filters are of brass with fine-mesh wire netting to support the filter cloth, and are hinged to facilitate removal for cleaning.

The exhaust system, designed to remove 35,400 cu. ft. of air per minute from the auditorium, has four main divisions as shown in the balcony plan, one leading to openings in the front of the stage, another to openings in the auditorium side walls beneath the balconies, and the other two to outlets in the balcony tier risers. The former has 24 inlet openings, each with an 8x24-in. register, designed for an inflow of 340 ft. per min. These inlets are connected to two trunk ducts, one 18x22 in. and the other 14x28 in. in section, which lead up at the left-hand side of the stage to the fan room, the exhaust capacity of this division being 10,870 cu. ft. per min. The auditorium sidewall division has twenty openings beneath the balconies on the inner or store sides of the hall only, each having a 12x18-in. register designed for an inflow of 290 ft. per min. This divison removes a total of 8,700 cu. ft. of air per min., the trunk duct connecting through an 18x38-in. riser to the exhaust system mains. The two balcony floor divisions have together 48 openings, each a 6x24-in. register, the system being designed for an inflow rate at these points of 290 ft. per min. Each half has a capacity of 6,960 cu. ft. per min., and connects with the exhaust system through a 28x18-in. riser duct. There are also auxiliary connections to the dressing and toilet rooms at the rear of the stage, which remove 1,910 cu. ft. per min. The exhaust fan is a 9-ft. full-housed blower, of a capacity of 35,400 cu. ft. per min. at 135 r. p. m., and is belt driven from a 30-h.-p. General Electric motor. It draws air from an exhaust chamber 10 ft. square, and delivers through a window opening upon the Fourth Ave. side. This fan and also the fresh air fan and heating stacks, are of the American Blower Co.'s make.


Fan No.1
Fan No.2
Fan No.3
Fan No.4
No.2 Pump
Reheater Coils
Reheater Coils
Inlet in Ceiling 10'2" x 2'10"
Inlet in Ceiling 16'3" x 2'10"
Inlet in Ceiling 15'2" x 2'10"
Inlet in Ceiling 15'2" x 2'10"
X
X
Engineering Record

Plan of the Fan Room in Sub-Basement, New Wanamaker Store.

The heating and ventilating installation was designed by the architects for the building, D. H. Burnham & Co., Chicago. It was installed, together with the steam plant and piping, by Gillis & Geoghegan, heating contractors, New York.

The Institution of Mechanical Engineers of Great Britain had a most prosperous record during 1905. According to the report of the Council, presented at the annual meeting last month, the membership comprises 9 honorary members, 2,427 members, 1,748 associate members, 72 associates and 494 graduates, a total of 4,750. The balance of revenue over expenditures was about $8,000. The total investments and other assets are about $370,000, and after deducting debentures and funds set aside for leasehold and debenture redemption, the Institution's capital is over $200,000. The Steam Engine Research Committee presented an elaborate report giving the results of eight years' experiments by Prof. Capper, and the Alloys Research Committee presented its seventh report, covering investigations of a series of iron-nickel-manganese-carbon alloys. The committee is now working on alloys of copper and aluminum.

The Chicago Drainage Canal Decision in the Supreme Court.

On Feb. 19 the United States Supreme Court delivered its decision in the action of the State of Missouri against the State of Illinois for the alleged pollution of the St. Louis water supply by Chicago sewage. The main suit has been before the court over six years. The taking of testimony occupied 317 days and nearly 300 witnesses were examined, of whom 35 were technical experts. The record in the case is the largest in the court's annals, the testimony taking up nine printed volumes of a thousand pages each. The opinion of the court reads as follows:

Nature of Suit.—This is a suit brought by the State of Missouri to restrain the discharge of the sewage of Chicago through an artificial channel into the Des Plaines river, in the State of Illinois. That river empties into the Illinois river, and the latter empties into the Mississippi at a point about 43 miles above the city of St. Louis. It was alleged in the bill that the result of the threatened discharge would be to send 1,500 tons of poisonous filth daily into the Mississippi, to deposit great quantities of same upon the part of the bed of the last-named river belonging to the plaintiff, and so to poison the water of that river, upon which various of the plaintiff's cities, towns and inhabitants depended, as to make it unfit for drinking, agricultural or manufacturing purposes. It was alleged that the defendant sanitary district was acting in pursuance of a statute of the State of Illinois and as an agency of that State. The case is stated at length in 180 U. S., 208, where a demurrer to the bill was overruled. A supplemental bill alleges that since the filing of original bill the drainage canal has been opened and put into operation, and has produced, and is producing, all the evils which were apprehended when the injunction was first asked. The answers deny the plaintiff's case, allege that the new plan sends the water of the Illinois river into the Mississippi much purer than it was before; that many towns and cities of the plaintiff along the Missouri and Mississippi discharge their sewage into those rivers, and that if there is any trouble the plaintiff must look nearer home for the cause.

The decision upon the demurrer discussed mainly the jurisdiction of the court, and, as leave to answer was given when the demurrer was overruled, naturally there was no very precise consideration of the principles of law to be applied that the plaintiff should prove its case; that was left to the future, with the general intimation that the nuisance must be made out upon determinate and satisfactory evidence, that it must not be doubtful, and that the danger must be shown to be real and immediate. The nuisance set forth in the bill was one which would be of international importance—a visible change of a great river from a pure stream into a polluted and poisoned ditch. The only question presented was whether, as between the States of the Union, this court was competent to deal with a situation which, if it arise between independent sovereignties might lead to war. Whatever differences of opinion there might be upon matters of detail, the jurisdiction and authority of this court to deal with such a case as that is not open to doubt; but the evidence now is on the actual facts, which have required for their establishment the most ingenious experiments, and for their interpretation the most subtle speculations of modern science, and therefore it becomes necessary at the present stage to consider somewhat more nicely than heretofore how the evidence is to be approached.

Jurisdiction.—The first question to be answered was put in a well-known case of the Wheeling bridge—Pennsylvania vs. Wheeling and Belmont bridge company, 13 Howard, 518. In that case also there was a bill brought by a State to restrain a public nuisance, the erection of a bridge alleged to obstruct navigation, and a supplemental bill to abate it after it was erected.

The question was put most explicitly by the dissenting judges, but it was accepted by all as fundamental. The chief justice observed that if the bridge was a nuisance it was an offense against the sovereignty whose laws had been violated, and he asked what sovereignty that was. (13 Howard, 561; Daniel, J., 13 Howard, 599. See also Kansas vs. Colorado, 185 U. S., 125.) It could not be Virginia, because that State had purported to authorize it by statute. The chief justice found no prohibition by the United States. (13 Howard, 580.) No third source of law was suggested by any one. The majority accepted the chief justice's postulate, and found an answer in what Congress had done.

It hardly was disputed that Congress could deal with the matter under its power to regulate commerce. The majority observed that, although Congress had not declared in terms that a State should not obstruct the navigation of the Ohio by bridges, yet it had regulated navigation on that river in various ways, and had sanctioned the compact between Virginia and Kentucky when Kentucky was let into the Union. By that compact the use and navigation of the Ohio, so far as the territory of either State lay thereon, was to be free and common to the citizens of the United States. The compact, by the sanction of Congress, had become a law of the Union. A State law which violated it was unconstitutional; obstructing the navigation of the river was said to violate it, and it was added that more was not necessary to give a civil remedy for injury done by the obstruction. (13 Howard, 565 and 566.)

At a later stage of the case, after Congress had authorized the bridge, it was stated again, in so many words, that ground of the former decision was that "the act of the legislature of Virginia afforded no authority or justification. It was in conflict with the acts of Congress, which were the paramount law." (18 Howard, 421-429.)

In the case at bar, whether Congress could act or not, there is no suggestion that it has forbidden the action of Illinois. The only ground on which that State's conduct can be called in question is one which must be implied from the words of the Constitution. The Constitution extends the judicial power of the United States to controversies between two or more States, and between a State and citizens of another State, and gives this court original jurisdiction in a caes to which a State shall be a party; therefore, if one State raises a controversy with another, this court must determine whether there is any principle of law; and, if any, what, on which the plaintiff can recover. But the fact that this court must decide does not mean, of course, that it takes the place of a legislature. Some principles it must have power to declare; for instance, when a dispute arises about boundaries, this court must determine the line, and in doing so must be governed by rules explicitly or implicitly recognized. (Rhode Island vs. Massachusetts, 12 pet., 657-737.) It must follow and apply those rules, even if legislation of one or both of the States seems to stand in the way. But the words of the Constitution would be a narrow ground upon which to construct and apply to the relations between States the same system of municipal law in all its details which would be applied between individuals. If we suppose a case which did not fall within the power of Congress to regulate, the result of a declaration of rights by this court would be the establishment of a rule which would be irrevocable by any power except that of this court to reverse its own decision, an amendment of the Constitution or probably an agreement between the States sanctioned by the legislature of the United States.

The difficulties in the way of establishing such a system of law might not be insuperable, but they would be great and new. Take the question of prescription in a case like the present. The reasons on which prescription of a public nuisance is denied or may be granted to an individual as against the sovereign power to which he is subjected have no application to an independent State. (See 1 Oppenheim. International Law, 293, sections 241-243.) It would be contradicting a fundamental principle of human nature to allow no effect to be attached to lapse of time, however long (Davis vs. Mills, 194 United States, 451, 457), yet the fixing of a definite time usually belongs to the legislature rather than the courts. The courts did fix a time in the rule against perpetuities, but the usual course, as in the instances of the statutes of limitation, the duration of patents, the age of majority, etc., is to depend upon the lawmaking power.

It is decided that a case such as is made by the bill may be a ground for relief. The purpose of the foregoing observations is not, then, to lay a foundation for departing from that decision, but simply to illustrate the great and serious caution with which it is necessary to approach the question whether a case is true. It may be imagined that a nuisance might be created by a State upon a navigable river like the Danube, which would amount to a casus belli for a State lower down, unless removed. If such a nuisance were created by a State upon the Mississippi, the controversy would be resolved by the more peaceful means of a suit in this court. But it does not follow that every matter which would warrant a resort to equity by one citizen against another in the same jurisdiction equally would warrant an interference by this court with the action of a State. It hardly can be that we should be warranted in declaring statutes ordaining such action void in every instance where the circuit court might intervene in a private suit, upon no other ground than analogy to some selected system of municipal law, and the fact that we have jurisdiction over controversies between States. The nearest analogy would be found in those cases in which an easement has been declared in favor of land in one State over land in another; but there the right is recognized on the assumption of a concurrence between the two States, the one, so to speak, offering the right, the other permitting it to be accepted. (Manville Co. vs. Worcester, 138 Mass., 89.) But when the State itself is concerned, and, by its legislation, expressly repudiates the right to set up, an entirely different question is presented.

Grave Importance of Suit.—Before this court ought to intervene the case should be of serious magnitude, clearly and fully proved, and the principle to be applied should be one which the court is prepared deliberately to maintain against all considerations on the other side. (See Kansas vs. Colorado, 185 United States, 125.) As to the principle of law to be laid down, the caution necessary is manifest. It is a question of the first magnitude whether the destiny of the great rivers is to be the sewers of the cities along their banks or to be protected against everything which threatens their purity. To decide the whole matter at one blow by an irevocable fiat would be at least premature. If we are to judge by what the plaintiff itself permits, the discharge of sewage into the Mississippi by cities and towns is to be expected. We believe that the practice of discharging into the river is general along its banks, except where the levees of Louisiana have led to a different course. The argument for the plaintiff asserts it to be proper within certain limits. These are facts to be considered. Even in cases between individuals some consideration is given to the practical course of events. In the black country of England it would not be expected to stand upon extreme rights. (St. Helens Smithing Co. vs. Tipping, 11 H. L. C., 642. See Boston Ferrule Co. vs. Hills, 159 Mass., 147, 150.) Whereas here the plaintiff has sovereign powers and deliberately permits discharges similar to those of which it complains; it not only offers a standard to which the defendant has the right to appeal, but, as some of those discharges are above the intake of St. Louis, it warrants the defendants in demanding the strictest proof that the plaintiff's own conduct does not produce the result, or, at least, so conduce to it, that courts should not be curious to apportion the blame. We have studied the plaintiff's statement of the facts in detail and have perused the evidence, but it is unnecessary for the purposes of decision to do more than give the general result in a very simple way. At the outset we cannot but be struck by the consideration that if this suit had been brought fifty years ago it almost necessarily would have failed. There is no pretense that there is a nuisance of the simple kind that was known to the older common law.

The River Contamination.—There is nothing that could be detected by the unassisted senses—no visible increase of filth, no new smell. On the contrary, it is proved that the great volume of pure water from Lake Michigan, which is mixed with the sewage at the start, has improved the Illinois river in these respects to a noticeable extent. Formerly it was sluggish and ill smelling; now it is a comparatively clear stream, in which edible fish have returned. Its water is drunk by the fishermen, it is said, without evil results. The plaintiff's case depends upon an inference of the unseen. It draws the inference from two propositions: first, that typhoid fever has increased considerably since the change, and that other explanations have been disproved; and second, that the bacillus of typhoid can and does survive the journey and reach the intake of St. Louis in the Mississippi. We assume the now prevailing scientific explanation of typhoid fever to be correct; but when we go beyond that assumption everything is involved in doubt. The data upon which an increase in deaths from typhoid fever in St. Louis is alleged or disputed, to the elimination of other causes, is denied.

The experts differ as to the time and distance within which a stream can purify itself. No case of an epidemic caused by infection at so remote a source is brought forward, and the cases which are produced are controverted. The plaintiff obviously must be cautious upon this point, for if this suit should succeed many others would follow, and it not improbably would find itself a defendant to a bill by one or more of the States lower down upon the Mississippi. The distance which the sewage has to travel (375 miles) is not open to debate, but the time of transit to be inferred from experiments with floats is estimated as varying from eight to eighteen and one-half days, with forty-eight hours more from intake to distribution, and when corrected by observation of bacteria is greatly prolonged by the defendant. Experiments of the defendant's experts lead them to the opinion that a typhoid bacillus could not survive the journey, while those on the other side maintain that it might live and keep its power for twenty-five days or more and arrive at St. Louis. Upon the question at issue, whether the new discharge from Chicago hurts St. Louis, there is a categorical contradiction between the experts on the two sides.

The Chicago drainage canal was opened on January 17, 1900. The deaths from typhoid fever in St. Louis before and after that date are stated somewhat differently in different places. We give them mainly from the plaintiff's brief: 1890, 140; 1891, 165; 1892, 411; 1893, 215; 1894, 171; 1895, 106; 1896, 106; 1897, 125; 1898, 95; 1899, 131; 1900, 154; 1901, 181; 1902, 216; 1903, 281. It is argued for the defendant that the numbers for the later years have been enlarged by carrying over cases which, in earlier years would have been put into a miscellaneous column (intermittent, remittent, typhoid malarial, etc.) but we assume that the increase is real. Nevertheless, comparing the last four years with the earlier ones, it is obvious that the ground for specific inference is very narrow if we stopped at this point. The plaintiff argues that the increase must be due to Chicago, since there is nothing corresponding to it in the watersheds of the Missouri or the Mississippi. On the other hand, the defendant points out that there has been no such enhanced rate of typhoid on the banks of the Illinois as would have been found if the opening of the drainage canal were the true cause.

Both sides agree that the detection of typhoid bacillus in the water is not to be expected; but that the plaintiff relies upon proof that such bacilli are discharged into the Chicago sewage in considerable quantities; that the number of bacilli in the water of the Illinois is much increased, including the bacillus coli communis, which is admitted to be an index of contamination, and that the chemical analysis leads to the same inference. To prove that typhoid bacillus could make the journey, an experiment was tried with the bacillus prodigiosus, which seems to have been unknown, or nearly unknown, in these waters.

After preliminary trials, in which these bacilli emptied into the Mississippi, near the mouth of the Illinois, were found near the St. Louis intake and in St. Louis in time varying from three days to a month, 107 barrels of the same, said to contain 1,000,000,000 bacilli to the cubic centimeter, were put into the drainage canal near the starting point on November 6, and on December 4 an example was found at the St. Louis intake tower. Four others were found on the three following days, two at the tower and two at the mouth of the Illinois. As this bacillus is asserted to have about the same length of life in sunlight in living waters as the bacillus typhus, although it is a little more hardy, the experiment was thought to prove one element of the plaintiff's case, although the small number found in many samples of water is thought by the other side to indicate that practically no typhoid germs would get through.

It seems to be conceded that purification by the large dilution from Lake Michigan (nine parts or more in ten) would increase the danger, as it now generally is believed that the bacteria of decay, the saprophytes, which flourish in stagnant pools, destroy the pathogenic germs. Of course, the addition of so much water to the Illinois also increases its speed. On the other hand, the defendant's evidence shows a reduction in the chemical and bacterial accompaniments of pollution in a given quantity of water which would be natural in view of the mixture of nine parts to one from Lake Michigan. It affirms that the drainage of the Illinois is better, or no worse, at its mouth than it was before, and makes it at least uncertain how much of the present pollution is due to Chicago and how much to sources further down, not complained of in the bill. It contends that if any bacilli should get through they would be scattered and feeble, and could do no harm. The defendant also sets against the experiment with the bacillus prodigiosus a no less striking experiment with typoid germs suspended in the Illinois river in a permeable sac. According to this, the duration of the life of these germs has been much exaggerated, and in that water would not be more than three or four days. It is suggested by way of criticism that the germs may not have been of normal strength, that the conditions were less favorable than if they had floated down in a comparatively unchanging body of water, and that the germs may have escaped, but the experiment raises at least a serious doubt. Further, it hardly is denied that there is no parellelism in detail between the increase and decrease of typhoid fever in Chicago and St. Louis. The defendant's experts maintain that the water of the Missouri is worse than that of the Illinois, while it contributes a much larger proportion to the intake.

Centering and Construction Plant for One Subway.

What St. Louis Should Do.—The evidence is very strong that it is necessary for St. Louis to take preventive measures, by filtration or otherwise, against the dangers of the plaintiff's own creation or from other sources than the Illinois. What will protect against one will protect against another. The presence of causes of infection from the plaintiff's action makes the case weaker in principle as well as harder to prove than one in which all came from a single source.

Some stress was laid on the proposition that Chicago is not on the natural watershed of the Mississippi because of a rise of a few feet between the Des Plaines and Chicago rivers. We perceive no reason for a distinction on this ground. The natural features relied upon are of the smallest; and if, under any circumstances, they could affect the case, it is enough to say that Illinois brought Chicago into the Mississippi watershed in pursuance not only of its own statutes, but also of the acts of Congress of March 30, 1822 (C. 14, 3 St. 659) and March 2, 1827 (C. 51, 4 St. 234), the validity of which is not disputed. (Wisconsin vs. Duluth, 96 U. S. 379). Of course, these acts do not grant the right to discharge sewage, but the case stands no differently in point of law from a suit because of the discharge from Peoria into the Illinois, or from any other or all the other cities on the banks of that stream. We might go more into detail, but we believe that we have said enough to explain our point of view, and our opinion of the evidence as it stands.

What the future may develop, of course, we can not tell; but our conclusion, upon the present evidence is that the case proved falls so far below the allegation of the bill that it is not brought within the principles heretofore established in the cause.

Bill dismissed without prejudice.

A WIRING FORMULA easily worked on the slide rule has been suggested by Mr. M. S. Howard. It is $n = 10 \log (500\ V \div D\ I)$, where n is the number of the wire, V the drop in volts, D the distance in feet, and I the load in amperes. After performing the operations indicated within the parenthesis, using the C and D scales, the 10 of the C scale will be found opposite a number on the D scale, which should have its logarithm read by means of the scale on the reverse side of the slide.

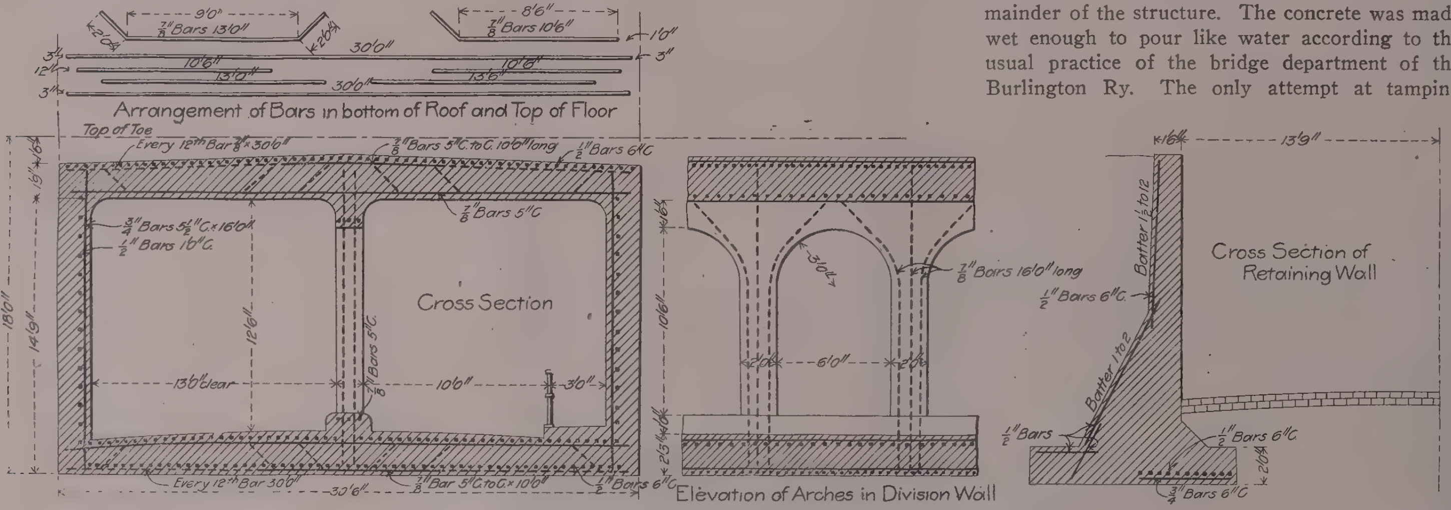
Reinforced-Concrete Subways on the Chicago, Burlington & Quincy Ry.

The Chicago, Burlington & Quincy Ry. is building a large classification yard at Galesburg, Ill., included in the construction of which are two under-grade highway crossings carried through reinforced concrete subways. One of these subways is 386 ft., and the other 420 ft. long, both of them providing for traffic on existing highways, extending across the site of the yard. Two highways intersect at right angles about 250 ft. to one side of the tracks near the south end of the yard and both of them cross the tracks, one at an angle of nearly 80 deg., and the other at an angle of about 20 deg. The two crossings have been combined in one at right angles to the tracks and just above the intersection of the two highways. A diagonal approach, 280 ft. long, extends from this intersection to one portal of the subway in which this crossing is made. This subway is 386 ft. long extending under the site of the yards. At the opposite end two approaches extend at right angles to the center line of the subway and parallel to the yard tracks, one connecting with the highway which formerly crossed the tracks at an angle below and the other connecting with the highway which crossed them above the subway site. The 420-ft. subway is located 1 mile above this one where another highway is carried under the site of the yard.

Design.—The land in the vicinity of the yard and the subways is practically level. Although some of the tracks in the yard are on embankments to provide the grades necessary for gravity operation, the subways had to be built entirely below the natural surface and low enough to provide for 1 ft. of ballast over their tops to carry the tracks. The general design of both subways is the same and is shown in the accompanying reproductions of various sections of them. The plans for the structure were developed from the standard designs of the bridge department of the Burlington Ry. for flat top box culverts. The barrel of each subway is rectangular in cross-section, 30.5 ft. wide and 17 ft. high overall. It has a flat-bottom floor, vertical sidewalls and a flat roof, with only sufficient slope on top for drainage. Each subway is divided longitudinally at the center by an arched wall which extends the length of the structure. A clear width of 13 ft. is provided between this division wall and each of the sidewalls, the minimum clear height being 12.5 ft. The highway traffic will be carried directly on the surface of the concrete floor. The traffic in one direction will pass through on one side and that in the other direction on the other side of the division wall. A pathway 3 ft. wide for pedestrians is also provided against one of the sidewalls.

The floor is 2 ft. 3 in. thick at the center, with its upper surface crowned until the thickness of the floor is 1 ft. 9 in. at its junction with the sidewalls. There being a probability that the floor will be subjected to upward hydrostatic pressure from ground water as well to the loads brought on it by traffic, the concrete is reinforced near both surfaces of the floor slab. The lower layer of reinforcement is placed 3 in. from the bottom surface. It consists of ½-in. bars placed longitudinally on 6-in. centers, and of ⅞-in. transverse bars, 10 ft. long, placed on 5-in. centers, with the middle of the bars on the longitudinal center line of the division wall. Every twelfth one of the transverse bars is 30 ft. long, extending under the sidewall at each end. The upper layer of reinforcement consists of longitudinal ½-in. bars, 6 in. on centers, the bars being placed to follow the crown of the surface and 6 in. below the latter. Directly under the longitudinal bars are ⅞-in. transverse bars spaced 5 in. on centers. These transverse bars are in sets of three, one 10.5 ft., the second 13 ft. and the third 30 ft. long. These are distributed uniformly and the ends of the short bars turned down to provide for shearing stresses, the floor being considered a beam loaded from below.

The side walls are reinforced 3 in. from the inner face only. This reinforcement consists of ¾-in. vertical bars, 5½-in. on centers, extending into the concrete of the top and bottom of the structure. Back of these bars are ½-in. horizontal bars placed longitudinally on 1-ft. centers to provide for longitudinal stresses. The arches in the division wall have 6-ft. spans, with bench walls 7 ft. high, above which the rise of the arch is 3 ft. The bench walls are 1.5 ft. thick and 2 ft. wide and are each reinforced with six ⅞-in. bars, three bars in a row near each side. These bars are 16 ft. long and are anchored at the bottom in the concrete of the floor. The tops of the end bars in each row of 3 are bent over the haunches of the arches, while the middle bar is vertical. The ⅞-in. horizontal bars are placed longitudinally 3 in. above the crown of the arches. The roof is built and reinforced practically the same as the floor with the exception that it is bottom side up when compared with the latter. The barrel of the subway is built without expansion joints, the longitudinal reinforcement being expected to provide for temperature stresses.



Arrangement of Reinforcement in Burlington Subways at Galesburg, Ill.

The diagonal approach to the subway carrying the two intersecting highways under the yard is 250 ft. long, and the two approaches at the other end of that subway are both 248.25 ft. long. The approaches to the other subway are both in line with the structure and are each 300 ft. long. The roads in the approaches are all built on a 5 per cent. grade and are to be paved with brick. The two parallel to the railroad tracks, on one end of the subway carrying the intersecting highways have a retaining wall on the railroad side, while the embankment on the opposite side is sloped. Buttressed reinforced-concrete walls were built where the height of the retaining wall exceeded 13 ft. As the cost of building that type of wall and a gravity section wall was found, under the conditions, to be about balanced below 13 ft. in height, the gravity section was adopted for the portion of the walls of less than that height. The sides of the approach at the opposite end of this subway are carried by retaining walls for 60 ft. from the portal; beyond the walls they are sloped. The sides of the approaches to the other subway are carried by retaining walls for 100 ft. from the portals.

The floors of both subways are 15 to 16 ft. below the surface of the surrounding ground and the latter is very flat in the vicinity of the subways. The run-off from the approaches is carried to the subways by gutters on each side of the roadways. A catch basin is placed on each side of both portals and other catch basins and manholes are distributed through the barrel of the subway as required. These basins are connected by 12-in. drains and the water is carried from each subway to an outlet by a 12-in. sewer. Owing to the depth of the floor below the surface and the extremely flat slopes of the surrounding country the sewer from the shorter subway had to be carried ¾ mile where it joins the sewer from the other subway, which is also nearly ¾ mile from this junction. The sewer from both subways is 12-in. hub and spigot vitrified sewer pipe laid with cement joints; a sewer is continued for about a mile from the junction of the two 12-in. laterals. The trenches for these sewers are from 10 to 21 ft. deep and were all dug by a Chicago trench excavator made by the Municipal Engineering & Contracting Co. The machine cut to the full depth of the trenches in passing over once. Some very heavy wet clay which occasioned much trouble in sheeting the trenches to prevent their sides from sliding, was encountered at different places and interfered greatly with the progress of the work.

Construction.—The construction of both subways was carried on in open trenches which were excavated by wheel scrapers and teams. In building the subway with the straight approaches, the contractor, Mr. James O. Heyworth, of Chicago, first laid a service track the length of the trench on one bank. A concrete mixing plant was set up on the opposite side of this track from the excavation and at about the middle of the subway site. A second mixing plant was placed near one end of the subway. The concrete materials were delivered to these plants from cars on some of the yard tracks which had been laid across the site of the subway before the construction of the latter had been commenced. A Smith mixer on skids was used at each plant, a platform for receiving materials being erected level with the charging hopper of the mixer. A service track was laid on an incline from one of the yard tracks to each of the receiving platforms and the materials were delivered to the latter in small dump cars which were hauled up the incline by a cable on a hoisting engine. The mixer at each plant discharged in skips on push cars on the service track parallel to the trench. Where concrete laying was in progress, a stiff-leg derrick, with a bull-wheel, and its hoisting engine were set on a platform on rollers over the service track. The skips were hauled by the derrick between the push cars and the position the concrete was to occupy. The derrick was moved along as the work required and one of the mixing plants was moved when the approaches were built.

The construction of the other subway was carried on by the regular forces of the bridge department of the railroad. Part of the concrete was made in portable mixers which could be hauled to the desired position and dumped after the concrete was mixed. Mixers holding about ½ cu. yd. were used in making the concrete for the floor of the subway and part of the walls. They were operated on runways on the bank of the trench and the concrete dumped from them to place down chutes. The remainder of the concrete was mixed in a 1-yd. mixer of about the same type. This mixer operated on a platform erected transverse to the subway and dumped into skips on cars on a service track along the bank. These skips were handled from the cars to place by a derrick mounted on an old steam shovel car.

The two subways required 7,200 cu. yd. of concrete, which was made of gravel and cement. The gravel was obtained from a pit which is practically free from clay, and it is of such character that no screening or grading was required. Several brands of Portland cement were used. The concrete was made in the proportions of about 1 of cement to 6 of gravel, 1½ bbls. of cement to the cubic yard being used in the roof, and 1¼ bbl. to the cubic yard in the remainder of the structure. The concrete was made wet enough to pour like water according to the usual practice of the bridge department of the Burlington Ry. The only attempt at tamping it in the forms was to work the stones back from the faces of the latter with a flat blade tamping tool. The lagging of the forms was 2-in. matched lumber dressed one side. Johnson corrugated bars were used for reinforcement, over 360 tons being required in the two subways.

Reinforced Concrete Piles.—A number of reinforced-concrete piles were driven to provide a foundation for a track scales and platform at the summit of one of the hump tracks in the yard. These scales are about 18 ft. above the ground on a sand fill made from cars. Fifty-two of the reinforced-concrete piles were driven into this fill by a drop hammer without a water jet. The piles are octagonal, 16 in. across the top, 16 ft. long, and tapered to a diameter of 12 in. at the bottom. They are also pointed for about a foot. The reinforcement consists of four ½-in. Johnson corrugated bars spaced equally around a circle concentric with the center of the pile, the bars being kept 1½ in. from the surface of the concrete. A No. 11 wire is wrapped around the outside of the bars to secure the properties of a hooped-concrete column. The piles are cast in moulds laid on the side. They are made of 1:4½ gravel concrete, and were seasoned at least three weeks before being driven.

An ordinary derrick pile driver, with a 2,500-lb. hammer falling 18 ft., was used in sinking them. A timber follower 6 ft. long and banded with iron straps at both ends was placed over the head of the pile to receive directly the hammer blows. The band on the lower end was 10 in. wide and extended 6 in. over the end of the follower. In this 6-in. space a thick sheet of heavy rubber was placed, coming between the head of the pile and the follower. Little difficulty was experienced in driving the piles in this manner, although 250 to 300 blows of the hammer were required to sink each pile. The driving being entirely through fine river sand there is every probability that any kind of piles would have been driven slowly. The heads of the first 4 or 5 piles were battered somewhat, but after the pile driver crew became familiar with the method of driving, no further battering resulted and the heads of most of the piles are practically uninjured.

The yard at Galesburg is being built under the direction of Mr. T. E. Calvert, chief engineer of the Chicago, Burlington & Quincy Ry. Mr. R. W. Willis, division engineer at Galesburg, has immediate supervision of the field work. The structures built in connection with the yard were designed by the department of bridges of the Burlington, Mr. C. H. Cartlidge, bridge engineer. The construction work was also carried on under the direction of Mr. Cartlidge.

The Completed Barrel of One Subway.

In Appropriating a water power the town of Harrisonburg, Va., has recently encountered a singular legal snag. It bought an existing dam and served notice on the riparian property owners above it that the dam would be raised 10 ft. Commissioners were appointed to fix the damages to the upstream property caused in this way, and one of the items they assessed against the town was $3,000 for the 10-ft. fall in the river due to raising the dam. The town protested against such an award because none of the riparian owners had property on both sides of the river, and consequently none of them owned any power privileges. The Virginia Supreme Court has decided, 52 S. E. Rep. 555, against this contention. It ruled that the town could not take by right of eminent doman the several parts of a valuable whole from different property owners without compensation. "The parts are equal to the whole, in law and in logic," the court said, "and if the entirety be of value, the parts which constitute the entirety must potentially be of an equal value."

The Burraga Dam.

The success of mining in Australia depends to a large extent upon the practicability of securing a permanent supply of water; and in many instances the richest mines are situated in the most arid localities, where there are no rivers or creeks, and where the evaporation and the absorption of the soil are so great that the conservation of any large quantity of water is a matter of extreme difficulty. The Lloyd Copper Co.'s mine at Burraga, New South Wales, is situated in broken and mountainous country at an elevation of 3,000 ft. above sea-level, and is reputed to be one of the best low-grade copper-ore mines in Australia. Hitherto the reduction of the ore has been carried out by roasting and the reverberatory furnace, the matte being sent 42 miles by road and 53 miles by rail to Lithgow, to be refined, before shipment to London; but now the company is erecting concentrating machinery and calciners, with a view to doubling or trebling the output, and it is estimated that 180,000 gal. of water per day will be required.

Before determining upon a concentrating plant, the company instructed Mr. John H. Cardew to make surveys and investigations of the surrounding country for the purpose of discovering a catchment-area sufficient for the purpose of supplying the requisite water. The valley of Thompson's Creek, a tributary of Isabella River, was selected as being the only practicable catchment-area available, and a favorable site was selected for the erection of a concrete dam about 3½ miles from the mine. Between this valley and that in which the mine is situated a watershed intervenes, and, in order to discover a route for a pipe-line to connect the reservoir and the mine which should not involve heavy tunnel-works, several trial surveys were made, and eventually a "gap" was found which admitted of the pipes being laid to the hydraulic gradient, with a comparatively short length of tunnel, about 25 ft. below the surface at the deepest part. An account of the water works has been contributed by Mr. Cardew to the "Proceedings" of the Institution of Civil Engineers, from which these notes are taken.

The catchment-area of the impounding reservoir embraces 5,329 acres of undulating and mountainous country, timbered principally with white gum and stringy bark. The upper portion of the drainage-basin is of granite formation, the hills being rock and lightly covered with soil. In the valleys the soil is very porous and sandy, but the lower portion of the creek valley in the vicinity of the dam is a slate formation, the overlying soil consisting of a stiff clay mixed with ironstone gravel, whilst the range of hills abutting on the north and east sides of the reservoir site consists of hard diorite.

The mean annual rainfall is 28.2 in. and the greatest rainfall ever recorded in one day is 3 in., the records having been kept for the last 10 years.

In determining the size of the dam and reservoir, and the quantity of water necessary to be impounded for the supply of the works at the mine, the liability to long periods of drought had to be considered. During the six summer months of the preceding year all the rain that fell was either evaporated or absorbed, and there was no flow in the creeks; it was therefore decided to make the storage equivalent to 1 year's supply, so that the continuous running of the machinery might be assured. As already stated, the requirements of the works were 180,000 imp. gals. of water per day, which, for 313 working days, is 56¼ million imperial gallons per annum; and to this must be added the quantity likely to be evaporated from the reservoir. The government astronomer of New South Wales, Mr. H. C. Russell, has for many years past carried out a series of observations on evaporation at Lake George, about 70 miles south of Burraga, and at an altitude of 2,267 ft. above sea level, the results of which show that the mean annual evaporation during the 10 years 1886-1895 was 40 in. As the climatic conditions at Burraga are similar in every respect to those at Lake George, Mr. Cardew assumed that Mr. Russell's conclusion would be applicable, and adopted 40 inches as the mean annual evaporation. The area of the reservoir is 31 acres, and 40 in. on that area is equivalent to 28¼ million gallons, which, added to the annual requirement of 56¼ million gallons, gave the storage required as 84½ million gallons, and the height of the waste weir was fixed accordingly.

As the flow in the creeks had never been gauged, it was impossible to calculate exactly how much water the catchment-area contributed to the streams and what proportion of the rainfall was lost by absorption and evaporation, but for a preliminary estimation it was assumed, after careful examination of the surface, that 65 per cent. was lost by these agencies. The average rainfall of 28.2 in. on the catchment-area of 5,329 acres, less 65 per cent., amounts to 1,193¼ million gallons, or sufficient to fill the reservoir fourteen times every year, leaving 1,108¾ million gallons to pass away down the creek to the settlers below the dam. Just before the dam was completed an opportunity occurred of actually measuring the amount of rainfall contributed to the reservoir, which proved that 72.8 per cent. of the rainfall was lost by evaporation and absorption on the catchment.

Trial pits and trenches were sunk right across the site of the dam, and what was supposed at the time to be sound rock was located, but when excavation for the foundations of the dam was commenced, and the whole site was laid bare, it was discovered that the rock was so laminated with nearly horizontal fissures, containing clay, gravel and wash, through which water was flowing, that it was found necessary to remove a much larger body of rock than was at first deemed sufficient, in order to secure a solid rock seat for the dam.

The dam is curved in plan, the inner face of the wall having a radius of 539.83 ft. The length of the crest measured on the curve is 425.58 ft., and subtends an angle at the center of 45 deg., 10 min. 10 sec., the versine being 41.40 ft. The dam is designed with a gravity section, and no reliance is placed upon any strength that may accrue on account of its curved form, as it was thought that the southern bank of the creek was not sufficiently abrupt to act as an abutment, the curved form being introduced only to minimize the effects of expansion and contraction. The center of gravity and center of pressure were determined graphically. The limit of pressure was assumed to be 10 tons per square foot and the density 170 lb. per cubic foot for concrete masonry. In cross-section the inner face of the dam is vertical, the outer face of the upper part being curved to a radius of 40 ft., and on the lower part battered to a slope of 1 horizontal to 1½ vertical. The greatest height of the dam is 41 ft., the width at the crest being 2 ft., and at the base 25.32 ft. The waste weir was designed as an overfall, and was placed at about the center of the dam, being calculated to provide for a rainfall of 3½ in. in 24 hours from a full reservoir with three-fifths flowing off.

During a long experience of flood investigation in New South Wales, and by the comparison of many observations compiled by the government astronomer, Mr. Cardew has found that the maximum rainfall for one day in this district is very nearly one-eighth of the mean annual rainfall, and that the maximum rainfall for one hour is nearly one-fourth of the greatest daily rainfall; in a period of eight hours the maximum rainfall is double that for one hour; in a period of sixteen hours it is treble, and in 24 hours four times as great as the rainfall for one hour. It was therefore assumed, for the purposes of calculation of the discharge over the weir, that the maximum rainfall for one day would be 3½ in., for one hour 0.87 in., for eight hours 1.76 in., and for sixteen hours 2.64 in.

Assuming that the rain is general over the whole area, and of sufficient duration to allow the flood-waters from all parts of the drainage-area to reach the dam at the same time, it was determined, after a careful examination of the creeks and gullies, and the slopes of the ground on the catchment-area, that at least eight hours would be required, after the rain commenced, to reach the moment of maximum discharge at the dam; and, allowing the ratio of diminution of discharge due to area to be $M\tfrac{3}{4} \div M$., the quantity in cubic feet to be discharged was calculated by the Chamier formula,

$$Q = 640 \times R \times C \times M\tfrac{3}{4},$$

in which R = average rate of rainfall in inches per hour $= 1.76 \div 8 = 0.22$ for a duration of 8 hours, C = coefficient of surface discharge, determined by inspection on the ground $= 0.60$, M = catchment area in square miles $= 8.3$, Q = quantity of water reaching outlet in cubic feet per second = 413 cu. ft. per second.

The length of waste weir required to discharge this rainfall with a depth on the crest of 1 ft. 3 in. was found from the formula,

$$L = \frac{Q}{m \times d \times \sqrt{2gd}},$$

in which $m = 0.30$, to be 123 ft., but as the inlet-well for the supply-valves projects above the crest of the dam and divides the waste weir into two separate parts, the clear combined width was made 125 ft. in order to allow for diminution of discharge due to the contraction at the ends.

The outlet-works consist of a semicircular well or valve chamber with two cast-iron outlet-pipes, 9 in. in diameter, laid side by side, leading therefrom through the wall of the dam and provided with stop-valves on their outer ends, one pipe being a reserve in case of emergency. The well is supplied from the reservoir by three 12-in. inlet-pipes, set at different levels in the semicircular wall of the well and controlled by valves supported on brackets and worked by spindles from the platform on top of the well, so that water can be drawn at any desired level. A sluice-pipe 18 in. in diameter is laid through the base of the wall for the purposes of cleaning out and regulating the discharge of the creek waters during construction. A light steel girder-bridge on top of the dam connects the valve-chamber with the shore.

After all laminated and decayed rock had been removed from the foundations, the surface was cleaned off by means of a jet of water at a pressure of 60 or 70 lb. per square inch, supplied by a pump, and all crevices and fissures were cleaned out and filled with cement grout, mixed in the proportion of 1 of sand to 1 of cement; a layer of cement mortar in the proportion of 2 of sand to 1 of cement was spread over the surface of the rock to a thickness of ½ in. before any concrete was placed in position. The concrete was laid in courses, 2 ft. in depth, extending from one end of the dam to the other, and was of two qualities, the inner face of the dam, for a thickness of 18 in., consisting of concrete composed of 1 of cement, 2½ of sand, and 3½ of crushed stone to pass through a ring ½ in. in diameter, and the outer face of the dam, for a thickness of 6 in., being of concrete composed of 1 of cement, 3 of sand, and 5 of crushed stone to pass through a ring 1½ in. in diameter. The heart of the dam was built of blocks of stone set in concrete, locally known as plum concrete, each stone having 6 in. of concrete all round, and no stone being laid nearer than 18 in. to the inner face of the dam, or nearer than 6 in. to the outer face, or within 2 ft. of the foundations; the stones were not larger than 16 cu. ft. nor smaller than 2½ cu. ft., and were roughly squared and placed with their longest dimensions at right angles to the axis of the dam. All the stones were scrubbed and hosed clean before being laid in the work.

To guard against the effects of frost, which was very severe at night during the winter months, work was suspended before sundown, and all new concrete was covered over with tarpaulins; before resuming work in the morning, the surface of the concrete was hosed down with boiling water before the next course was placed in position. Diorite stone of excellent quality was obtained within ½ mile of the dam, its only fault being that it was too hard for the stone-breaker, the jaws of which frequently failed.

The stone in passing through the crusher produced comparatively little sand or dust, and it was found that the admixture of a small proportion of the dust with the concrete produced a very beneficial effect both upon the setting of the concrete and upon its strength. The sand used in the concrete was of a very coarse character and quite unsuitable for making a water-tight dam, but the admixture of the dust from the crusher greatly improved the quality of the concrete in that respect. Portland cement was employed. The tests of the neat cement showed a tensile strength of 529 lb. per square inch after 3 days, 607 lb. after 7 days, and 664 lb. after 28 days. The tests of cement mixed with three times its weight of sand showed a tensile strength, after 7 days, of 229 lb. per square inch, and after 28 days 284 lb. The specific gravity of the concrete in the dam was found to be 2.724.

Stout timber centers were erected the full height of the dam, and the casing was erected as the work proceeded. Great care was observed in bedding the stones in the concrete to avoid cavities, and the concrete was thoroughly punned around them; the concrete on the faces was well worked with spades to get a smooth surface when the timbers were struck. It was found that the proportion of "plums" was 33 per cent. of the whole wall.

When the dam had reached a height of about 20 ft. above the bed of the creek, a heavy fall of rain occurred on the drainage area, causing a freshet in the creek, which the sluice-pipe was insufficient to deal with, and the water rose behind the wall to some height. Owing to the immaturity of the concrete masonry, the water forced a passage through a joint, causing a leak just above the root of the apron. In order to plug the hole in the face of the dam and such interstitial voids as might exist in the heart of the masonry, liquid cement was injected under hydraulic pressure. An iron tank holding 400 gal. was placed on the hillside 50 ft. above the leak. A 2-in. wrought-iron pipe was laid from the tank down the slope of the hill to the leak at the foot of the dam, and was connected at one end to the tank, the other end being provided with a valve and a short length of flexible pipe terminating in a nozzle, which was inserted into the orifice of the leak in the face of the dam. The face of the dam for 6 ft. above and below the hole and on either side was then planked over with 2-in. hardwood planks, tongued and grooved, with insertion laid between the face of the wall and the planking, a hole being bored through the plank over the leak to allow the nozzle to pass through. The planking was strengthened with hardwood stringers, 4 by 4 in., which were strutted back to the rock and wedged up to hold the planking against the face of the dam and make it water-tight under pressure; the nozzle was then inserted and made perfectly secure and tight by driving home and wedging.

The tank on the hill was filled with liquid cement kept in a thoroughly mixed state by men with shovels, and when everything was in readiness the valve was opened and about one-third of the mixing passed down the pipe into the hole. After an interval of 3 days the shores and planking were removed, and it was seen that the hole had been most effectually filled with the cement grout, which, when the water rose behind the dam to its full height, was found to be quite water-tight. Although the greatest care was observed in the mixing and laying of the concrete to secure a water-tight wall, it was recognized that the coarseness of the sand would greatly militate against success in spite of the inner face of richer concrete, and it was found as the dam progressed and the water rose in the reservoir that a considerable leakage occurred, which appeared on the down-stream face of the dam like water coming from a very fine rose. To render the inner face with cement mortar made from such coarse sand would not improve matters; it was therefore decided to paint the inner face with neat cement mixed to a slurry, applied with stiff brushes, and well rubbed into the pores in three successive coats; this proved most effective, for when the water rose again in the reservoir the wall was found to be perfectly water-tight.

The expansion and contraction in concrete dams when the reservoir is low is very great, and when the reservoir is full it is very unequal in different parts of the cross-section; this is especially the case in some parts of Australia, where hot days and cold nights are of frequent occurrence, giving a range of temperature of about 90° F., and on that account many of the concrete dams in this country are badly cracked. In order to obviate this tendency to some extent, and to assist the closing of the cracks as the reservoir filled, the curved form of dam was adopted. It has been observed that the curved form does not render the structure altogether immune from cracking, and the cracks occur generally at about one-third of the length of the dam from the wings, commencing at the crest, first as a very fine crack and afterwards opening out and extending down the wall a distance of one-third to one-half of its height, and opening and closing as the reservoir empties or fills.

It was thought that the introduction of an iron tie-bar in the crest of the dam, to take the tensile stress due to the contraction, would completely preserve the dam from cracking. It has been proved in other works that the temperature in the heart of the dam is constant, from which it may be argued that in order to ensure safety from cracking it is only necessary to protect from tensile stress the upper or thinner part of the dam where the cracks invariably originate. Two 70-lb. rails would be theoretically sufficient, but in order to provide a margin of safety three 70-lb. double-headed rails were laid, 6 in. below the level of the weir-overflow, and were jointed with fish-plates and embedded in the concrete.

The pipe-line is 16,890 ft. in length and conforms to the principal contours of the intervening hills, crossing a low-lying gap in the dividing-range, through a tunnel 1,100 ft. in length. The pipe is 9 in. in internal diameter and is constructed of mild wrought steel ⅛ in. in thickness. It is constructed in lengths of 24 ft., the plates being 4 ft. in length. The longitudinal joints are 1¾ in. and the transverse joints 1⅛ in. in width; the rivets are 5/16 in. diameter and ⅞ in. pitch; the longitudinal joints are double-riveted, the pitch-lines being ¾ in. apart, and the cylindrical joints are single-riveted. Each pipe is fitted with a welded and rolled socket shrunk on, riveted and caulked, the sockets being 3½ in. in depth. Spigots are formed by welding the pipe-end to make it seamless, a welded ring 5 in. in width and ⅛ in. in thickness being then shrunk on and secured by counter-sunk rivets. All seams have a tarred canvas insertion and were machine-riveted and caulked. The pipes were tested by hydraulic pressure to 200 lb. per square inch and were then dipped in a hot bath containing a mixture of equal quantities of bitumen and distilled tar. The pipes are laid to regular gradients, and at all bends, horizontal and vertical, cast-iron pipes curved to 50 ft. and 25 ft. radius are inserted, and all joints, both in the steel and in the cast-iron pipes, are made with spun yarn gasket and run in with lead in the ordinary way. Across deep gullies the pipes are carried on concrete pillars, expansion-pieces being inserted at one end of the exposed pipe. Air-valves are provided at all summits, and scour-valves in all dips. At the end of the pipe-line a small storage-tank of 10,000 gal. capacity is provided, from which other tanks on the mine are supplied. The actual discharge by measurement was found to agree closely with the calculated delivery of 220,500 gal. per day for which the pipe was designed.

The cost of the works, exclusive of the land, was £14,661, of which the dam cost £9,566 and the pipe-line £5,095. The land for the masonry dam and reservoir and part of the pipe-line was obtained from the Crown under the provisions of the Mining Act, but as part of the pipe-line passed through private lands, special arrangements had to be made with the proprietors for way-leave. In all cases, however, the conditions under which the land was obtained were very satisfactory. The following are the costs of the materials per cubic yard used in the concrete:

Rubble Stone.

	s.	*d.*
Quarrying and explosives	4	6
Cartage (1 mile)	2	0
Total	6	6

Broken Stone (1½ inch and ½ inch).

	s.	*d.*
Quarrying and explosives	4	6
Cartage (1 mile)	2	0
Crushing	1	6
Total	8	0

Sand.

	s.	*d.*
Getting & carting 2 miles (no washing necessary)	4	9

Cement.

	£	*s.*	*d.*
Cost per cask weighing 3 cwt. 2 qr. 7 lbs.	0	11	6
Freight by rail 149 miles from port of Sydney	0	4	4½
Freight by road 42 miles	0	5	4
Storage and handling	0	0	4½
Commission	0	0	1½
Total	1	1	8½

The work was carried out under contract by Mr. John Ahearn, of Sydney, from whose accounts the following particulars of net cost for the two classes of concrete have been compiled:

	Per cubic yard. £	*s.*	*d.*
Cement	1	5	1½
Sand	0	2	3¼
Broken stone (½-inch gauge)	0	5	4¾
Timber and labor in fixing	0	2	6
Labor in mixing and laying	0	3	6
Net cost of plant, including erection, removal and freight, after deducting proceeds of sale	0	0	11
Total	1	19	8½

1:2½:3½ concrete.

for which the contractor was paid £2 per cubic yard.

	Per cubic yard. £	*s.*	*d.*
Cement	0	14	8
Sand	0	1	7
Broken stone (½-inch gauge)	0	4	6
Rubble plums	0	1	1½
Timber and labor in fixing	0	2	6
Labor in mixing and laying	0	3	6
Net cost of plant, including erection, removal and freight, after deducting proceeds of sale	0	0	11
Total	1	8	9½

1:3:5 concrete and rubble plums.

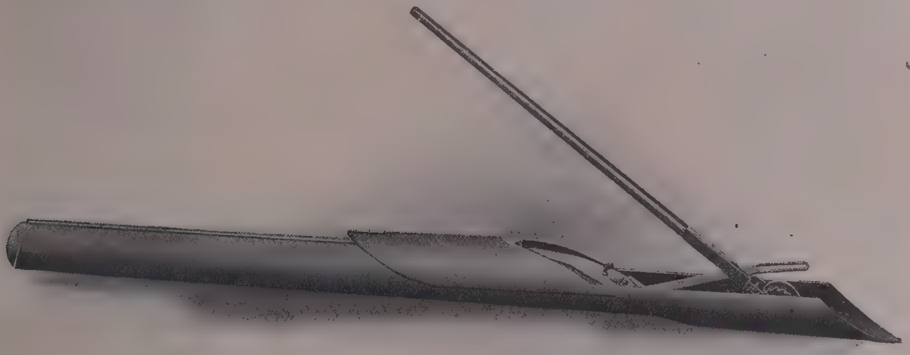
for which the contractor was paid £1 14s. 4½d per cubic yard.

The Paper is accompanied by two drawings, from which the Figures in the text have been prepared.

Method and Cost of Constructing Cement Pipe in Place.

By Halbert P. Gillette, Consulting Engineer, New York.

The method of making cement pipe in place which I shall briefly describe, is an invention of Mr. Ernest L. Ransome. Some years ago he made his first successful attempt at building cement pipe with a movable mold, but the stress of business has prevented his perfecting this system until recently. A few weeks ago when I was in Rochester, N. Y., I went out to Despatch to see the reinforced concrete factory buildings that Mr. Ransome was erecting for the Foster Armstrong Piano Co. Among the various interesting features of this extensive work, none interested me as much as the cement pipe sewer work then under way. An 8-in. pipe was being built at the rate of 1 lin. ft. per minute, by six men and a foreman. The men were working with great energy, and the records show that they actually averaged about half this rate, their average being 300 lin. ft. per 10-hour day.



Mold for Making Cement Pipe in Place.

As shown in one of the illustrations, three men work in the trench, one of the men packing the cement mortar in the mold, one continuously pulling the mold ahead by means of the lever and the third filling around the green pipe with earth. The other three men mix mortar and deliver it into the trench.

Before giving the cost of this pipe, a word as to the method of construction: The mold is made of sheet steel with an inner core 10 ft. long. The front end of this core is surrounded by a short steel shell that serves as the outer form for the cement pipe. The mortar for the pipe is packed in between the inner core and this outer shell by a man who uses a small wooden rammer for the purpose, as shown in the illustration. The man standing in the foreground keeps moving the mold forward slowly by means of the lever grasped in the right hand. This lever is provided with a dog that works in a ratchet, and thus rotates a small drum upon which a wire rope is wound. The wire rope is anchored into a deadman in the trench ahead. As the mold is thus moved forward it leaves behind it the cement pipe, which is still green. The cement mortar, however, is mixed with a small amount of water so that it possesses sufficient cohesion to hold together when unsupported by the core. To protect the pipe until it hardens, it has been found advisable to pack a little earth around its sides and over the top; this is done by the third man in the trench, and he does this backfilling upon the part of the pipe that is still supported by the core.

In verbally describing this feature of the construction I have invariably been asked two questions: 1. Does the pipe not cave in occasionally, especially when it is of large diameter? 2, How are branches put in?

Answering the first question, Mr. Ransome says that caving does not occur except when some heavy object falls on the pipe before the cement has hardened. The pipe does not break down of its own weight even when made 3 ft. in diameter.

To put in a branch a hole is cut in the side of the green pipe before the core has been pulled ahead. A branch of the proper pattern is shoved up tightly against the pipe, and the collar of the branch is plastered with cement mortar, producing a strong water-tight joint.

The following was the itemized cost of an 8-in. cement pipe built as afore described:

6 men at $1.70 per day, 10 hours	$10.20
1 foreman	2.00
3 bbls. cement at $1.25	3.75
3.3 cu. yds. sand at 85c	2.80
Water	.15
Total for 300 lin. ft.	$19.90

This is equivalent to 6.63 cents per lin. ft. of pipe. Let us compare this cost with that of vitrified pipe. The list price of 8-in. vitrified pipe is 50 cents per ft. and the present discount is about 70 per cent., making the cost of the pipe 15 cents per ft. It costs about ½ cent to haul, 1½ cents to lay, and ½ cent for cement, making a total of 17½ cents per ft. as compared with the 6.63 cents above given for cement pipe built in place. It should be added that the shell of this particular 8-in. cement pipe was made unusually heavy, being 1½ in. thick.

On another stretch of 12-in. pipe the cost was as follows:

	Per Day.
7 men at $1.70	$11.90
1 foreman	2.20
13 bbls. cement at $1.33	17.30
12 cu. yds. fine gravel at 80c	9.60
Total for 400 feet of pipe	$41.00

This is equivalent to 10¼ cents per ft., as compared with about 35 cents per ft. for 12-in. vitrified pipe laid. In none of these cases is the cost of digging the trench included in the labor item, for that cost is common to all kinds of pipe sewers. However, due to the fact that there are no bells on the cement pipe and no joints to be made, the trench can be dug about 6 ins. narrower than where vitrified pipe is used, effecting considerable saving in the cost of excavation.

Roughly speaking, vitrified pipe and labor of laying (not including trenching) costs about three times as much as cement pipe built in place, when prices are as above given; nor are the above records in any sense "record-breakers" for low cost. I noted that in building the 8-in. pipe the men in the trench were capable of putting in pipes at the rate of 1 lin. ft. per minute, which was just about twice what they averaged for the whole job. The speed depends very largely upon the man who is packing the mortar into the mold, and as this is hard work, it would be advisable to let him change places frequently with the man who works the lever that pulls the mold ahead. By having two strong and willing men in these positions, I believe that 500 lin. ft. of 8-in. pipe could be built in 10 hours, day in and day out.

In closing, a word about the field of usefulness of this kind of cement pipe. Obviously, cement pipe built in place is much cheaper than vitrified pipe at present prices. That it is likely to remain cheaper seems probable when we consider the fact that, with the exception of the cement, the materials used are raw materials, and that they are usually to be had without long freight hauls. Economy in first cost seems, therefore, assured where cement pipe is used. How about the economy of maintenance and effectiveness for the purpose intended? One of the common defects of pipe sewers is leakiness; this results either in the escape of sewage where the surrounding soil is dry, or in the entrance of ground water where the surrounding soil is charged with water. With joints at 2 or 3-ft. intervals, it requires the greatest care in construction to prevent leakiness. The continuous cement sewer does away with this objection to pipe sewers entirely.

As for durability, the long experience that Brooklyn has had with cement pipe sewers answers this question so satisfactorily that I need not dwell upon it. There appears, therefore, to be no reason why the continuous cement pipe should not be used wherever its first cost is less than the first cost of vitrified pipe.

By the use of trench-digging machines and molds for building cement pipe in place, it is possible to provide towns and small cities with sewers at a cost amazingly low compared with present costs. To make it possible for contractors to use cement sewers, however, engineers must call for bids on alternate plans. Bids on reinforced concrete sewers are being called for in competition with bids on brick sewers, and little by little, contractors are finding out that concrete is cheaper. In like manner, I look to see engineers take the initiative in building continuous cement pipe sewers. Of course, it would be practicable for contractors to take the initiative by offering to substitute cement pipe for vitrified pipe at lower prices.

While I have laid particular stress upon the use of cement pipe for sewers, its use is obviously not confined to sewers only. As a matter of fact one of the first lines of cement pipe built by Mr. Ransome was in St. Paul and it was built to carry water.

A Hawaiian Pumping Plant for Irrigation.

Method of Using Mold.

The Makee Sugar Company, on the island of Kauai, Hawaiian Territory, of which Mr. Z. S. Spalding is president, is installing an interesting pumping plant for irrigation. The primary driver will consist of a specially designed impulse water wheel, operating under a fall of 400 ft. of water, and delivering its power continuously to a Bullock alternating-current generator, direct-connected, at six maximum speeds, which are secured by the use of six different sets of buckets arranged on wheels of varying diameters.

Mountain streams are not very numerous in the Hawaiian Islands and are usually in comparatively inaccessible places, rendering it impossible to lead the water by means of flumes or ditching to the land to be irrigated. Furthermore, it is frequently the case that, while the quantity of water available is small, the head is comparatively great, thus enabling a large amount of horse-power to be obtained. Under such conditions an electric generator driven by a water-wheel may be installed at the falls and the power generated there transmitted to a distant pumping plant located but a few feet above sea-level, which obtains its supply from wells or underground tunnels. At such points the quantity of water available is usually abundant. The fundamental engineering problem, is, therefore, to utilize a small quantity of water under a high head to raise a large quantity of water to a comparatively load head.

As is the experience with mountain streams elsewhere, the quantity of water Mr. Spalding has available for power varies considerably at different seasons; hence, he wishes at all times to utilize, as far as practicable, the maximum water supply, and, in order to get the full benefit from the quantity available at any time, it has been necessary to evolve a scheme by which speed of the pump can be varied in proportion to the flow at the source of power. The head being constant, the velocity of the water at the delivery nozzle is constant, and the horse-power varies directly with the water supply. By changing the dimensions of the wheel carrying the buckets, the rotative speed of the generator is changed, while the speed of the water remains constant at all times.

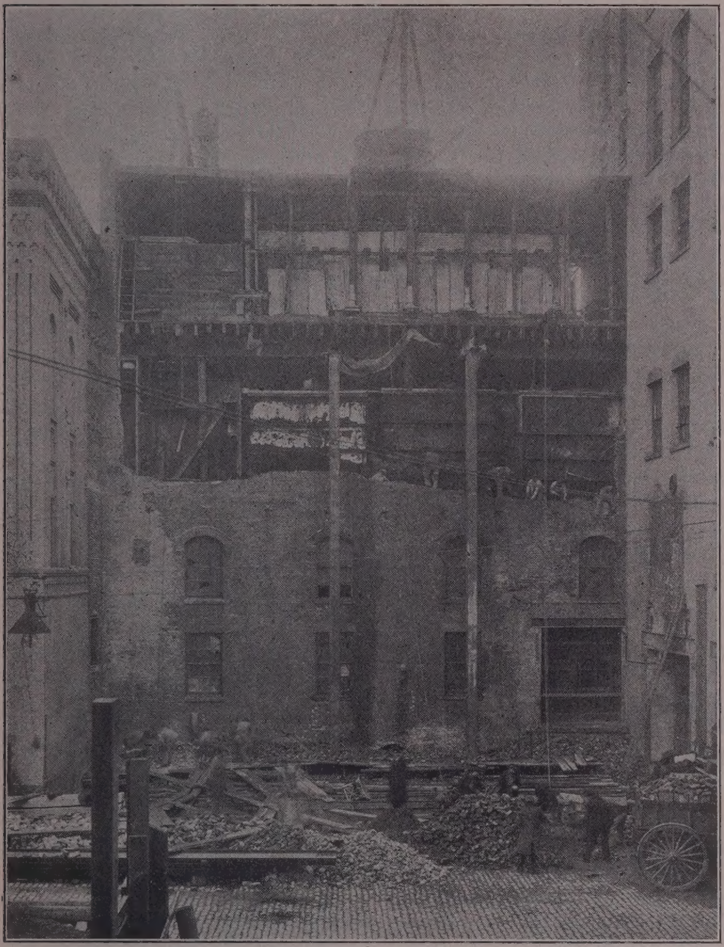
With constant field strength on the generator, the voltage will be directly proportional to the rotative speed and, as the cycles are also proportional to the rotative speed, it will be seen that the volts and cycles vary in a fixed ratio to each other. The energy from the generator being delivered to an induction motor, the speed of the motor, and therefore of the pump, will change in the same proportion as the speed of the generator. As both the frequency and the voltage change in the same ratio, the induction motor will at all times be operating under conditions corresponding to those for which it has been designed. The generator is rated at 300 kw., three-phase, 60 cycles, and will have a normal speed of 450 r.p.m.

The pumping plant will be located five miles from the power sttaion. Here is to be installed a Bullock induction motor of 225 h.-p., and this, by means of rope transmission, will drive a duplex, double-acting Riedler pump, having a capacity, against 250-ft. head (including friction), ranging from 1,750 gal., when the water wheel has 5 cu. ft. per second supply of water, to 2,800 gal. per minute (4,032,000 gal. per 24 hours) with a supply of 8 cu. ft. per second at the wheel. The speed of the pump, operated at its full capacity, will be 116 r.p.m. It is to be extra heavy and furnished with Allis-Chalmers Co.'s latest improved mechanically-operated pump valves.

The generator will have its exciter, of 8 kw., direct-connected to it, and the exciter has been so designed that it can deliver the full voltage and current required for excitation even at the minimum speed. By means of an automatic regulator, the exciter voltage will be maintained constant at all speeds of rotation and it will, therefore, be unnecessary to change the adjustment of the generator rheostat when the speed of rotation is changed. In addition to the automatic regulator a hand-operated field regulator will be installed for use in an emergency. It was the original intention to use at the pumping station a synchronous motor, which would require a 50-h.-p. motor for starting, as well as an exciter, controllers and apparatus for throwing the starting motor in or out; but it was found that the system could be simplified by the use of an induction motor. The operation of the plant remains otherwise practically the same, and of course the induction motor requires neither a starting motor nor exciter, but merely controlling apparatus. The efficiency of the whole plant will be the same with an induction motor as with a synchronous motor, while in simplicity of construction, reliability of operation, small amount of attention required, and also in the matter of first cost the induction motor has the advantage. Necessary by-pass valves are provided for use in starting up. Either side of the pump may be run separately when desired.

Lofty Shoring in a Brewery.

Improvements in Doelger's Brewery, on 55th St., near First Ave., New York, include the removal of about 50 ft. of a brick wall about 60 ft. high and the extension of the building into the courtyard beyond it. The wall carried the ends of longitudinal steel and wooden beams in four floors and the roof and it was necessary to support these temporarily by vertical wooden shores until the steel beams and columns of the new structure can be erected. In the basement, engine room, and pump room stories this was easily accomplished by the use of a row of sixteen 12x12-in. vertical timbers seated on horizontal 12x12-in. sills in the basement parallel with the wall which was to be removed. These timbers were cut in one-story lengths and took bearing at both ends, with pairs of oak wedges and fillers when necessary, on the original floor or on transverse distributing beams on the floor at their lower ends and at their upper ends were wedged directly against the lower sides of the longitudinal floor beams.

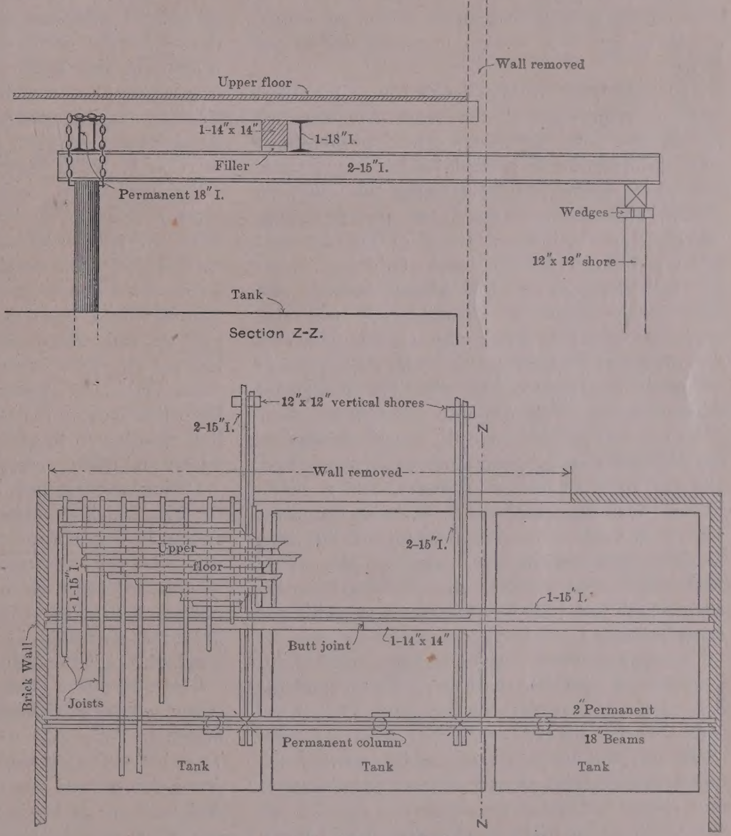


Court Wall Partly Removed, Showing Inside and Outside Shores.

The third story of the building is occupied by three 26x50-ft. brine tanks 11 ft. deep, which are covered over on top so as to virtually form an intermediate floor in the third story. These tanks occupy the full width of that portion of the building where the repairs are in progress and made it impossible to continue the system of shoring described for the lower stories through the upper part of the building. Special provision was therefore made for supporting one floor and the roof above the brine tanks.

The tanks were carried by the brick wall and by three cast-iron columns about 18 ft. apart in a transverse row, parallel with the wall and 15 ft. distant from it. The columns pass through the tanks and carry a double line of 18-in. transverse I-beams which support on their top flanges the longitudinal wooden beams of the upper floor. They were utilized as supports from which were suspended in U-bars, supplemented by heavy chain slings, the inner ends of two pairs of 18-in. horizontal longitudinal I-beams about 28 ft. long. The outer end of each pair of beams projects about 6 ft. beyond the face of the wall to be removed and is supported with a transverse bearing block and wedges on the upper end of a vertical 14x14-in. timber about 60 ft. long. The lower end of the timber is adjustable with two sets of double wedges and is seated on timber cribwork, giving it a bearing of about 28 square ft. on the level surface of the ground in the courtyard. A transverse line of 15-in. I-beams made with two pieces overlapping at the joint extends across the full width of building midway between the permanent I-beam girder and the wall and is supported intermediately on the pairs of suspended beams above described. The ends are seated in the brick side walls of the building. Parallel with the line of I-beams is a 14x14-in. beam supported in the same manner and made with two pieces of timber having a butt joint spliced with side planks bolted on. This I-beam and timber carry the upper floor-beams which are wedged to bearing on their top flanges. A tier of vertical shore timbers like those described in the lower stories carries the roof beams from the cantilever beams.

The basement has a height of about 8 ft., the engine room 22 ft., the pump room 9 ft., the tank room 22 ft., the attic 8 ft. in the clear, making a total height of over 70 ft. for the building including the thickness of roof and floors. It is estimated that the shores under the tanks carry a total of about 200 tons and that the two 70-ft. shores under the outer ends of the suspended beams carry about 30 tons each. Their wedges are carefully examined daily and there has been no indication of any yielding so that it has been considered unnecessary to brace them. The shoring contains about 10,000 ft. of timber b. m. and was placed in about ten days by six men in the employ of the contractors, Miller, Daybill & Co., inc., Brooklyn, N. Y., Messrs. McCuter & O'Brien are the builders, and the work was executed under the supervision of Mr. Alfred Daybill, of the contracting firm.



Plan and Section of Girders over Tanks.

The Design of an Isolated Power and Lighting Plant.

At a recent meeting of the Electrical Engineering Society of Columbia University, Mr. Putnam A. Bates read a paper on "Isolated Plant Engineering," which, after discussing the various economic and engineering features of isolated plants illustrates their application by an account in detail of a specific plant.

This plant consists of several machine shops for doing both heavy and light work, a forge shop, a pattern shop, a storage loft for patterns and an office building. Power for the operation of machinery in the various shop buildings was originally supplied by two steam engines located at different points in the works, each supplied with steam from a single boiler nearby and each driving a long line of shafting by means of a belt.

In time these engines became worn out and were discarded and a number of electric motors were substituted for them, a semblance of individual drive being installed in some of the shops. Current for these motors and also for some lighting was obtained from the public service mains in the street, and distributed from a switchboard in one of the shop buildings.

The two old boilers, however, were retained and kept in commission as the steam was needed for driving a couple of small air compressors in the boiler plate shop, a high pressure hydraulic pump used to furnish water under pressure for the operation of hydraulic tools, and a steam hammer in the forge shop, and for heating the various buildings.

This arrangement was obviously uneconomical both in operating cost and in space occupied, and it was therefore decided to install a central power generating plant where all of the power required by the works could be economically generated, and without occupying valuable space in the shops with boilers, feed pumps, coil piles or non-productive machinery. The space allotted to the power plant building was approximately 35 ft. wide by 60 ft. deep running back from the street to one of the shop buildings.

These, then, were the conditions, and the problem was how best to meet them to secure the greatest economy of operation and the greatest return on the necessary investment. The first question to be answered was with regard to the type of plant to be installed.

The high pressure steam-driven hydraulic pump and, if necessary, the steam-driven air compressors could be replaced by electrically driven apparatus, but no suitable substitute for the steam hammer has as yet been marketed and no form of heating is so well suited to the conditions which prevail at these works as that using direct radiation from steam or hot water.

As the advantage gained by the operation of the steam hammer, and the saving which could be accomplished during about six months of the year, by the use of exhaust steam for heating purposes, far outweighed any possible saving in the cost of power production which internal combustion engines might perhaps be able to show in comparison with steam-driven apparatus, the latter type was chosen in preference to the former.

The next point to be decided was the total capacity required and the most advantageous sub-division into units. In order to obtain as much information as possible which would serve as a guide to help in determining this question, careful observations were made of the power consumption at different times of the day and under different conditions, and of the size, number and character of the various motors and tools in the shops. A careful study was also made of the coal, water and electric bills for the preceding five years in order to ascertain as nearly as possible how the load conditions changed from month to month and year to year.

As a result of this analysis, it was decided to install three electric generating units, two of 60, and the third of 30 kw. capacity, and a single steam-driven air compressor, it being unnecessary to provide a reserve machine of this type as the temporary crippling of this machine would shut down only a small portion of the works and would not interfere in any way with the other portions.

The type of prime mover and the relative advantages of operation with or without condensers came up next for consideration. A careful comparison of operating efficiency, first cost, floor space occupied and general suitability of the various types of high speed reciprocating engines and steam turbines, showed a very decided advantage in favor of the vertical compound reciprocating engine as applied to the conditions which were found to exist.

To determine the total boiler capacity required, it simply remained to ascertain the amount of steam which the engines selected will consume when furnishing the requisite power, as determined by the manufacturers' guarantees, and to add to this the amount of steam which will be consumed by the steam hammer. In this manner it was found that 300 h.-p. in boiler capacity would be sufficient, the horse-power rating being based upon the well-recognized standard of 34½ lb. of water evaporated per hour from and at 212° F. The desirability of reserving some space for future enlargement of the boiler plant led to the choice of two boilers each rated at 150 h.-p. set in a battery.

A cross drum type of boiler with 14-ft. tubes was used in order to make it possible to set the boilers across the building, which arrangement was the most economical of floor space and lent itself best to the steam piping arangement, and at the same time to remove and renew tubes as occasion should require. The boilers are built for a working pressure of 200 lb., but only 150 lb. will be carried. They are equipped with a superheater designed to give 100° of superheat.

The building for housing the apparatus decided upon is a two-story brick and steel fireproof structure having the boiler and engine room on the first or ground floor, and a 100-ton steel coal bin on the second floor, the remaining portion of the floor being available for manufacturing or other purposes. A steel plate chimney, 4 ft. in diameter, and with its top 125 ft. above the boiler room level, also rests upon the second floor and is connected with the flue openings of the two boilers by means of a steel plate flue and breechings.

Coal is delivered by means of a chute from the sidewalk to a bucket conveyor running from a pit in the first floor, into which the chute opens, to a point above the coal bin on the second floor. This conveyor is entirely enclosed and provided with a spout at the top by means of which the coal is deposited near the center of the bin. A motor on the second floor drives the conveyor by a belt.

The boilers are located in a room by themselves, the side wall of the setting being carried out to form a partition wall between the engine room and the boiler room. This arrangement necessitates the cleaning of one of the boilers from the engine room, but was necessary in order to obtain sufficient room for a possible future increase in boiler capacity.

The coal bin is located directly over the firing space in front of the boilers and has two pockets, from the bottom of each of which hoppers are carried down to a height of about 5 ft. above the boiler room floor and terminates in valves.

Under these hoppers a small coal charging car runs on rails set in the cement floor, and from this car the furnaces are supplied. This arrangement makes it unnecessary to carry any coal upon the floor of the boiler room, and, therefore, it is possible to keep this portion of the plant in a neat and cleanly condition.

Owing to cramped space and the nature of the soil, which prevented excavating to any great depth, it was not possible to make any special provision for the removal of ashes, even if the quantity of these were sufficient to warrant the necessary expense, which would be involved in providing for this in any other way than by hand, through the ash pit doors.

The feed-water heater is of the open type, the steam entering through an oil separator and mingling with cold water trickling over trays. Two boiler-feed pumps are installed, one being steam-driven and the other electrically driven. Although the latter is much more costly than a steam pump of the same capacity its much higher economy of operation amply warranted the additional expenditure.

The three generating sets are installed in a row along one wall and on the other side of a central aisle is the air compressor, the electrically driven boiler-feed pump, space for an additional electrical generating set and a controlling and distributing switchboard.

The generators are direct-current, 240-volt, compound-wound machines. The primary reason for the choice of this current and voltage was that all of the motors installed throughout the works were wound for that and the use of it makes it possible to take advantage of the public service as an auxiliary should it ever prove desirable to do so.

The lighting is taken care of by means of a three-wire system, fed from a rotary balancer installed near the switchboard. This arrangement was considered preferable to the use of a 240-volt, two-wire lighting system for the reason that this higher voltage does not lend itself well to the operation of many of our higher power illuminants, such as the arc lamp, so useful in the economical lighting of large enclosures.

The switchboard consists of seven panels of marbleized slate mounted upon an angle iron frame, and set 3 ft. from the wall. There is a generator panel for each of the three dynamos, a total output panel, an equalizer or balancer panel and a lighting feeder and power feeder panel.

Each of the generator panels is equipped with a single lamp bracket, an ammeter, a field rheostat, a three-pole switch, the middle pole of which performs the functions of an equalizer switch, and double-pole, double-arm, laminated contact circuit-breaker with carbon breaks.

Upon the total output panel are two single lamp brackets, a power ammeter, a light ammeter, a recording ammeter for the total current, a two-pole, double-throw switch, controlling the total current, one side being connected to the bus-bars and the other left blank for possible future connection to the public service, a registering watt-hour meter for showing the total amount of electrical energy generated, a double-pole power switch and two smaller double-pole switches, one controlling the supply of current to the equalizer panel and the other to the circuit feeding the electrically-driven boiler-feed pump.

The equalizer panel is equipped with two single light brackets, an ammeter for indicating the amounts of current flowing in the neutral wire of the three-phase system, and its direction, and a voltmeter for indicating the voltage on either side of this system—each of these instruments has the zero in the center of the scale and reads to the right and left—a voltmeter switch, the balancer field rheostat, a three-pole, double-throw switch for the control of the supply of current to the lighting feeder panel, one side being connected to the bus-bars and the other left blank for possible future connection to the public service, a switch and starting box for the control of the balancer and a double-pole circuit breaker.

The circuit-breaker embodies a construction which is rather peculiar in that the actuating coil is connected to the neutral wire from the balancer, while the blades are connected to the positive and negative wires, respectively, of the three-wire system. By this arangement an excessive unbalancing of the lighting circuits which would overload the balancer would trip the breaker and open the outside legs of the system, thus protecting the balancer from overloads without runing the risk of an abnormal increase of potental of one side or the other of the system, which would, to say the least, be detrimental to the life of the lamps.

Each of the feeder panels is equipped with two single lamp brackets and a number of feeder switches from which feeders are run to various points through the works.

On top of the switchboard a large illuminated dial voltmeter and a potential indicator of the same size and type are mounted. These are connected to a voltmeter switch on one of the generator panels, and to the main bus-bars respectively.

To this switchboard are connected the circuits for controlling the generation of the current and its distribution throughout the works.

A somewhat knotty problem was presented in connection with the air compressor. The amount of water necessary to cool the air compressor was estimated at 50 gal. per minute. The only available supply of water was from the city mains, and the cost of this amount from that source was too great to be considered. It was finally decided to install a cooling tower upon the roof through which the water could pass, after becoming heated in the jackets of the compressor, and be cooled and used again. By this arrangement only sufficient water is drawn from the street mains to make up the loss by evaporation, which is about 5 per cent., and the cost of the necessary electrical energy for moving the water is trifling compared with the saving accomplished.

The total investment necessary to accomplish this result was about equal to the cost of the water for one year if this water were allowed to run to waste after being used in the jackets.

Book Notes.

A little book that will prove welcome to a good many readers of this journal is Dr. A. A. Woodhull's "Personal Hygiene." The engineer's duties make him so familiar with the necessity of careful maintenance of machinery in order to preserve its efficiency and lengthen its period of usefulness, that he appreciates the maintenance problem of the human mechanism. Dr. Woodhull's previous work on "Military Hygiene" is already familiar to many engineers who have been put in charge of field work, for it is a favorite guide to camp and expeditionary sanitary matters. His new book is the substance of a course of lectures delivered before the undergraduate students at Princeton University, and is a manual that will interest anybody who appreciates the importance of physical and mental health. It is an eminently sane discussion of what to do to keep the body and mind in a good working condition; there are none of the exaggerated statements about food, tobacco, alcohol, exercise and other topics that have been exploited by cranks and ignoramuses in books and pamphlets without number, but there is plenty of good advice, clearly stated and logically arranged. (New York, John Wiley & Sons, $1.00.)

A little book on "Ventilation of Buildings" just issued in the well-known Van Nostrand Science Series gives the substance of lectures by Messrs. Wm. G. Snow and Thomas Nolan before the students of the architectural department of the University of Pennsylvania. It is a very satisfactory little work, fully up to the high average of this series, and without any sacrifice of accuracy it gives the important facts of ventilation in such a clear way that a reader without technical education can understand the subject. The calculations which must be made for ventilating installations are not discussed, as the subject is covered in a companion volume by Mr. Rafter. The authors first explain the general principles of ventilation and outline all the laws on the subject in the leading American cities, as well as the recommendations made by sanitarians and engineers. The different systems of ventilation are next taken up, and there are interesting discussions of fans and blowers, the relative merits of plenum and exhaust systems, aspirating coils, downward ventilation and upward ventilation. The final chapter is a description of the installations most suitable for residences, school buildings, churches, halls and court-rooms, theaters, hospitals, asylums, office buildings, department stores and manufacturing buildings. (New York, D. Van Nostrand Co., 50 cents.)

Five years ago the first edition of the "Practical Electric Railway Hand Book" by Mr. Albert B. Herrick was published and since that time it has enjoyed an unusual popularity, both among engineers engaged in railway work and in technical colleges, where it has been used to a considerable extent as a textbook. This popularity is easily explained by the essentially practical nature of the book, which gives in condensed form the data and information the author has found useful in his work as a consulting electric railway engineer. Since it appeared there has been considerable progress in a number of features of the equipment of such roads, and some sections of the book have been found hardly complete enough to answer reasonable demands for the latest information. For this reason a new edition has been prepared, containing corrections of all errors detected in the book up to the beginning of the current year and considerable new data, in addition to a revised form of those sections which seemed to need rewriting. Special attention may be drawn to the descriptions of new methods of testing that are described; in fact, probably the best part of the book is the section devoted to tests of various kinds. The work as a whole retains the same characteristics that marked the first edition. It opens with a selection of tables used by the electric railway engineer. This section is followed by one on testing, already mentioned, after which track is taken up. The power station, the line, the car house, the repair shop and the rolling stock are discussed in the order mentioned, and the book concludes with a few pages on operation. (New York, McGraw Publishing Co., $3.00.)

Letters to the Editor.

Improved Ventilation and Heating.

Sir: As your paper has always taken a leading stand on the subject of heating and ventilation I thought you might be interested to know how the Municipal Heating Co. of this city suggests a method of improved heating and ventilating in a circular letter to their customers, which I enclose. The same will speak for itself.

"In talking with an expert heating engineer, of how to economize in the use of steam, he gave the following instance of how steam may be wasted, without the knowledge of the consumer: Two brothers resided in twin houses, similar in size and construction. One brother, having limited means, exercised some care in the use of his steam, in order to reduce his heating bills; the other brother enjoying a much larger income, made no effort to economize in this way. Upon comparing notes, the brothers were astonished to find that—for some unaccountable reason—the rich brother's bill for heating was only half the size of the poorer brother's. They at once placed the blame upon 'defective meters,' which, after being interchanged, gave the same result, and an investigation of the pipe system within their houses showed a slight advantage in the piping system in the poorer brother's house. Each house was then inspected by a representative of the heating company, and upon an examination it was disclosed that the fireplace in the house of the poorer brother showed a slight draught, while in the case of the fireplace in the other house it was found that the flue was closed, the owner explaining that some years before he had had it bricked up. Thereupon the poorer brother had a damper put in his flue, so that it might be closed when not in use, resulting in the immediate reduction in his heating bill. The above incident is cited merely to illustrate one of the many instances where steam has been wasted, and may suggest to you some method of economizing."

This same company notified their customers during the fall and mild winter that it is also very wrong to open any windows to admit any fresh air that may possibly come in contact with their steam pipes.

Very truly yours, Edward Jay.
Syracuse, N. Y.

Power Plant Economics.

Sir: Mr. Stott's most valuable paper in your issue of Feb. 3 will be of great interest to all connected with power plant design.

European engineers will be surprised to find a modern steam plant unprovided with superheaters. Mr. Stott's proposal to substitute a low-pressure steam turbine for the low-pressure cylinder of a reciprocating engine seems worth trying; but as regards his suggested combination plant, say half producer gas engines and half steam turbines, it is very doubtful whether such a combined plant could compete commercially with a modern steam plant. The thermal efficiency of a producer gas engine may be more than double that of a steam engine or turbine; but if a modern steam plant has boilers adapted for the efficient combustion of cheap small coal, its total working cost per kilowatt is likely to compare very favorably with that of any producer gas plant.

No evidence is available to show that any appreciable work at all has been obtained from the heat in the exhaust gases from producer gas engines; and in any case Mr. Stott's suggestion that all such heat could be utilized in boilers, superheaters and economizers, would be found quite impracticable.

There is an obvious error in Mr. Stott's Table 1, which is intended to give an analysis of the heat losses in a year's operation of his plant. In this table Mr. Stott gives his average loss of heat to stack as 22.7 per cent., and he assumes that this item could be reduced to about 12.7 per cent. and possibly to 10 per cent., by scientific methods in the fire room. But of his four tests Fig. 4 is the only one that confirms this 22.7 per cent. loss, and this test refers to scientific working with semi-bituminous coal mechanically fired and checked by a CO_2 recorder. Under these conditions Fig. 4 shows an average of 11.4 per cent. CO_2, which corresponds to say 2,850° Fahr. furnace temperature. If the gases left the boiler at 647°, then the loss of heat in them would be 22.7 per cent., and if the economizer reduced them down to 453° Fahr., the final net loss to stack would be 15.9 per cent., which is the result indicated in Table 1.

But Fig. 3 shows clearly that, without such scientific methods, the combustion of the same semi-bituminous coal on these moving-bar stokers only averaged 6.8 per cent. (1,700° Fahr.); so that if the gases left at the same temperatures as above, the normal loss of heat in the gases must have been 38 per cent., or 26.6 per cent. net loss after passing through the economizer.

Of course it is hardly practicable to reduce the temperature of escaping gases much below 453° Fahr., so the results shown in Table 1 are evidently very much better than the average year's working, and being based on the test as per Fig. 4, they evidently show about the best result practicable with this plant.

As the loss of heat in ashes is only 2.4 per cent., radiation and leakage only 8 per cent. and loss to stack 22.7 per cent. (total heat losses at boiler, 33.1 per cent.), the boiler efficiency is 66.9 per cent.; but the economizer reduces these losses by 6.8 per cent. to 26.3 per cent., so that the combined efficiency of boiler and economizer on such test would be 73.7 per cent., while the net loss of heat to stack is only 15.9 per cent.

As the boilers are evidently worked within their rating, apparently evaporating not over 3 lb. steam per sq. ft. of boiler heating surface, there is no reason why this excellent result should not be maintained, provided the stokers will not burn out at the furnace temperature of, say, 2,850° Fahr., corresponding to 11.4 per cent. CO_2. It is certain that when using the Jones or Erith underfeed grateless stokers, which have no working parts in contact with fire, an average exceeding 12 per cent. CO_2 can be maintained without deterioration to the stokers.

Figs. 1 and 2 show that when burning anthracite, which is necessarily hand-fired, the efficiencies are much worse than with semi-bituminous coal mechanically fired. Fig. 1 shows that anthracite fired in the ordinary way showed only 4.7 per cent. CO_2 (1,175° Fahr.), when on the above basis the loss to the stack was no less than 55 per cent., or 38.5 per cent. after passing the economizer; and Fig. 2 shows that even with the scientific method only 7.6 per cent. CO_2 (1,000° Fahr.), was reached, when the apparent loss was 34 per cent. at boiler, or 23.8 per cent. after passing the economizer.

It may safely be stated that it is quite impracticable in normal working conditions to reduce the heat loss to the stack much under 15 per cent., or to get a boiler efficiency much above 75 per cent. The only way to do better, even on test, is to force up the furnace temperatures; and Mr. Stott's Fig. 5 shows that with gases escaping at 500° Fahr. above atmosphere, theoretically perfect combustion (21 per cent. CO_2), would be necessary if the loss to the stack were to be reduced to 10 per cent.; and of course this result is quite unattainable.

Yours faithfully, Erith's Eng'g Co., Ltd.
London, Feb. 21.

Sir: I have read with great interest Mr. Erith's criticism of my recent paper on "Power Plant Economics." In reply to his comments on the utilization of all the heat in the exhaust gases, I do not see why we should not utilize all the heat from these gases, provided we allow the proper losses in conversion of this heat to electricity in exactly the same manner as in an ordinary furnace and boiler. Due allowance was made for these losses in my paper, the only losses cut out being those due to ashes and to incomplete combustion, as they evidently do not exist in the exhaust gases of the internal combustion engine from which we are trying to extract as many heat units as possible.

In at least one factory in the Pittsburg district the exhaust gases from internal combustion engines are being used to heat the buildings.

Another possible source of economy, not mentioned in my paper, is the return of the exhaust gases, after passing through the superheater, boiler or economizer, to the gas producer, thus utilizing the CO_2 contained in them in the production of CO for the gas engine.

In reference to Mr. Erith's discovery of an error in Table 1, showing loss of heat to stack of 22.7 per cent.; from a comparison of this item with the CO_2 records, I should have stated more clearly perhaps that the CO_2 curves shown do not refer to the plant from whose records Table 1 was compiled, but to another under my charge in which experimental investigations on the combustion of fuel were being carried out.

Table 1 was compiled from a complete year's records in daily logs showing output in kilowatt-hours, coal consumption, coal analysis, ashes produced, ash analysis, water consumption, water and steam temperatures at all points, pyrometer readings at various points, the average of flue gas analysis of chemical department and other data. From this it will be seen that as Mr. Erith's argument is based upon the supposition that Figs. 1, 2, 3 and 4, showing CO_2 records were used in the compilation of Table 1, his whole conclusion is erroneous, and a careful perusal of my paper will show that the method of deriving Table 1 was clearly indicated, and, further, that the CO_2 curves were referred to only as "a series of tests made with this instrument" and no reference is made showing any connection between them and Table 1. Yours truly,

New York, March 5. H. G. Stott.

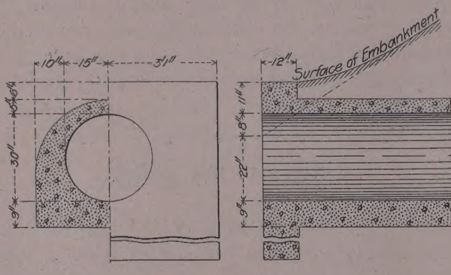
Standard Concrete Barrel Culverts.

Sir: Enclosed please find blue-print and table giving dimensions of concrete barrel culverts which are being built on a branch line of the Missouri Pacific Ry. at Springfield, Mo. The mixtures are, by volume, 1 part Portland cement, 3 parts sand and 5 parts broken stone or gravel. Gravel is preferable to broken stone and a wet mixture is also preferable because, in the limited space within the forms, tamping cannot well be thorough.

Dimensions of Concrete Culverts.

Diameter.	Thickness in inches. Base.	Springing.	Crown.	Length. Headwall.
18 in.	7	6	4	3 ft. 10 in.
24 in.	8	8	4	5 ft. 0 in.
30 in.	9	10	5	6 in. 2 in.
36 in.	10	12	6	7 ft. 6 in.
42 in.	11	14	7	8 ft. 8 in.
48 in.	12	16	8	10 ft. 0 in.

The centerings used are wooden and are collapsed by knocking apart the cross braces or heads. The barrel is made in four sections, each a quarter of a cylinder. On account of having to practically rebuild the forms for each culvert, the use of the collapsible steel centerings, which are on the market, would be economical. For openings 18 to 48 in. in diameter, this form of culvert is very satisfactory.



Standard Concrete Culverts.

Yours truly, Geo. W. Corrigan.
Springfield, Mo.

Street Bounds.

Sir: In regard to location of street bounds published in The Engineering Record of Feb. 3, I do not agree with the writer in his method of laying out streets or the placing of stone bounds. The matter of using curves in streets has been answered in the Record of Feb. 24, and I also fail to see why curves are not as easily located as tangents if the proper information is put on record.

The writer of Feb. 3 states, in regard to placing stone bounds anywhere except on the side line of streets: "The inconvenience of this scheme (meaning placing bounds in the street) is altogether too apparent for discussion." I wish to ask him if he does not have to make an offset in running a great many of his lines in town where the bounds are set on the side line of the street, and if it would not be a much better plan to have the bound originally set on an offset and so stated in the record. The bound set on the side lines is more apt to be disturbed by the digging of building foundations and the putting in of fence posts, especially at the corner of a street. He also says to use one corner of a rough stone bound for the starting point. This may be well enough for some kinds of work, where there is not a call for accurate instrument and chain work, but it is no more trouble to have a small drill hole in the center and then you have a well-defined point, whereas the corner of a bound may be more or less chipped off and not a good point from which to start.

In regard to the width of location, it would be very unwise to lay out all the streets in one county the same width. Some would be too wide and others too narrow for their present and future use. An engineer is called upon to use some discretion as to the proper width of the proposed streets, upon what traffic it will have. It is a waste of money to build a wide street where a narrow one would do as well, as much as it is to build a narrow one where a wide one is needed, and just as much of an engineering failure.

Boston, Mass. A. H. Peterson.

Checking Grade Stakes.

Sir: I notice in your last issue an inquiry as to the necessity of checking grade stakes on railroad construction. I think if the inquirer has ever been actively engaged in railroad work the practice in his locality is much different from that of any place I was ever fortunate enough to get into. The usual thing in my experience has been for the contractors to be ready for the work about as fast as the assistant in immediate charge of the work could by any possibility get stakes set for the opening of cuts. In many cases it was necessary to give such stakes as were sufficient to allow opening the cut and then hurry to another place to repeat the performance, all in order to allow the contractor to open such work as was for his convenience, real or imaginary, as the case might be. If the writer of the inquiry has been fortunate to be employed where the resident engineers had time enough to check the elevation of grade pegs, or to make up his estimates without losing time from sleep, he has my congratulations. It is of course understood that the levels of the center line are carefully re-run before the work of staking out begins, and I have made a practice in addition to test each station when staking out for construction. This I do by getting the required reading of the rod before the rodman reaches the station and then trying the rod on the station plug to see if it agrees with the computed reading. These things take practically no time to carry along with the work, but there is usually absolutely no time to check anything after once marked for the contractors. The resident engineer on railroad construction is usually a very much overworked man and the question usually is not what he would like to do, but what must be done to keep the contractors from kicking up a row for want of lines for the work they want to open.

Rockland, Me., Feb. 27. O. H. Tripp.

[This inquiry has been submitted to the engineers of several systems and it is interesting to observe the opposite views held. Two extracts from letters will show this fully. Mr. James Dun, chief engineer of the Atchison, Topeka & Santa Fe system, stated: "The checking of levels on railroad location is customary and important, and this work should be done before construction is undertaken to any extent." Mr. E. J. Beard, principal assistant engineer of the Chicago, Rock Island & Pacific Ry., stated: "It is not customary to check grade stakes. The man who cannot practically do such work without making damaging errors is incompetent. All calculations and measurements pertaining to any structure appearing on a plan should be checked; when staked on the ground by a novice, again checked; but an experienced man will not duplicate his work, although he will intuitively check himself by conducting his work so as to check on closing or otherwise, if practicable. It is all a matter of judgment, involving the determination of the point where expensive accuracy begins."]

A Forgotten Charge of Dynamite in a slag pile at the Carnegie Steel Co.'s plant at Pittsburg was recently exploded by a steam shovel that was excavating from the pile and accidentally struck the charge. The shovel was entirely destroyed, the bursting of its steam boiler adding to the violence of the explosion and causing great fatality.